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DEVELOPMENT OF THE SPECIAL OPERATIONS COMBAT MANAGEMENT SYSTEM

by
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14. ABSTRACT The Special Operations Combat Management (SOCM) System Program was an aggressive, fast paced research and development project which used advanced microelectronics packaging technology to design, build and test a state-of-the-art, high end Pentium computer. The computer was packaged into a small, but rugged, body-worn configuration, and was integrated with other items to become a complete wearable soldier information system suitable for use by members of the Air Force Special Operations Command. The system was integrated with military radios, commercial Wireless Local Area Network (LAN) technology, Global Positioning System (GPS) and a Mission Software package to provide personnel with advanced computer assisted information management, communications and navigation capabilities. The prototype SOCM wearable computer was completed in less than seven months from contract Authorization to Proceed, and the four deliverable systems were completed in less than one year. The resulting product, the SOCM wearable computer, was successfully tested in Operational Experiments with the 24th Special Tactical Squadron of the Air Force Special Operations Command, and has shown that the use of wearable computers can be a viable approach for information management in the military and Special Operations community.					
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Preface

This report documents the development and lessons learned in the process of the research, design and build of the Special Operations Combat Management (SOCM) System, sponsored by the Defense Advanced Research Projects Agency (DARPA), for the Office of Special Technology. The resulting product, the SOCM wearable computer, was successfully tested in Operational Experiments with the 24th Special Tactics Squadron of the Air Force Special Operations Command. 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 advanced technology is a challenging and formidable task that requires hard work, dedication, creativity and vision. The Boeing Special Operations Combat Management (SOCM) System team would like to acknowledge the following key individuals -- who played a large role in this program -- for their support, focus and direction.

Dick Urban, PM Defense Advanced Research Projects Agency (DARPA), for funding this program and for his focused vision in advanced technologies for DoD warfighters. With Mr. Urban's program management, direction and assistance, the program was linked to the dynamic mission of the USAF Special Operations Forces as the testbed for the SOCM system development.

Henry Girolamo, PM Soldier Systems Center, for the day-to-day operational program management and supervision. Mr. Girolamo's tireless efforts connected the development team with human factors specialists and user representatives ensuring continuity, interoperability and linkage between the development team and user so that the system would be a coherent and seamless electronic information system for the warfighter in the field.

Erik Syvrud, Office of Special Technology, was the user representative that discovered the performance enhancement utility that a body-worn computer would have for the USAF 24th Special Tactics Squadron. Mr. Syvrud provided the proponenty development, access to the 24th Special Tactics Squadron and an operational experiment using the systems, resulting in an initial path to transition the system to Special Operations Forces warfighters.

Johnny Pantages, Wintec, Inc., supporting the Office of Special Technology, also for his work as a user representative, and for his vision and advocacy of the system. Mr. Pantages provided additional linkage into the 24th Special Tactics Squadron, and first hand understanding and insight into the mission requirements, having served as member of the unit himself.

Jim Sampson, U.S. Army Soldier Systems Center, for providing human factors expertise, and oversight and guidance in the development of the user surveys.

MSgt Randy Dykes, TSgt Bruce Dixon, and Sgt Eric Vollmer, USAF 24th Special Tactics Squadron, for their participation in the test and evaluation of the SOCM System. Each took a deep interest in the system and contributed many hours in support of the evaluation. Their efforts have greatly enhanced our understanding of how to apply advanced mobile information technology to the benefit of the Special Operations soldier.

Robert (Bob) Reyes and Les Wolfe of Tactical Technologies Inc. (TACTEC), for their creativity and innovation as members of the design team, and for their knowledge, guidance and unique insight into the mission requirements, as previous STS operators themselves. Mr. Reyes and Mr. Wolfe also functioned as the on-site interface to the users.

DEVELOPMENT OF THE SPECIAL OPERATIONS COMBAT MANAGEMENT SYSTEM

1.0 Introduction

The information age has arrived in the military of today, and will continue to play an increasingly important role in the future. Real time battlefield information is becoming increasingly available to the soldier through such advances as Global Positioning Systems (GPS), satellite communications, an astonishing array of special sensors and detectors and eventually, the Battlefield Tactical Internet. With such a monumental increase in information availability, now what is needed is a method for linking of resources and sharing of data at not only the command level but at the level of the individual warfighter. A similar information revolution took place in the '80's in the civilian world with the establishment of the Internet, and the desktop personal computer surfaced as the interface device of choice due to its low cost and its increasing applicability to everyday life.

While the Battlefield Tactical Internet is currently in development, the soldier interface device has yet to fully emerge. For the dismounted soldier, a desktop device of any kind is out of the question for mobility reasons. What is needed is a device not only man-portable, but minimally obtrusive compared to the array of other essential equipment that must be carried. Ideally, the device should allow hands-free operation and be so fully integrated with the body that it is unnoticeable. The device must also be rugged, lightweight and low power, and should allow peripheral communication to other essential military devices such as Global Positioning Systems (GPS) and secure military radios.

In 1996, the Boeing Company (formerly McDonnell Douglas), under Defense Advanced Research Projects Agency (DARPA) funding on the Smart Modules program, began a feasibility study to explore the use of wearable computers with soldiers of the Air Force Special Operations Command (AFSOC). The program grew out of the Boeing's earlier endeavors to develop a body worn maintenance platform called the Maintenance and Repair Support System or MARSS. The MARSS system was a Pentium 133MHz wearable computer that could be used to remotely run weapon system diagnostics and perform remote lookup of repair procedures. The MARSS system was initially the baseline platform for the Special Operations program, but it quickly became evident that a much more rugged, compact and lightweight solution was needed to be compatible with the combat soldier's application. As a result of the Phase I feasibility study, a new baseline configuration was established for a system to be tailored for the Special Operations soldier. The new system was renamed to the Special Operations Combat Management (SOCM) System and is shown in Figure 1.



Figure 1. The Special Operations
Combat Management System

2.0 Program Description

The SOCM program was structured as a two-phase program, consisting of an up-front six month feasibility study, followed by a one year prototype build and test phase. During the feasibility study, members of the Air Force Special Operations Command (AFSOC) were interviewed, and the potential benefits of wearable computer technology to their operations were explored. Concepts and design features were developed and evaluated, and a system design approach was solidified prior to beginning the prototype build and test phase. The detailed design was developed, built and tested over the next year, and operational experiments were conducted with the AFSOC unit to verify and test the approach, and identify the strengths and weaknesses of the system design.

2.1 Schedule

Description	1996			1997			1998		
Phase I Kickoff Meeting		6/21							
Phase I Feasibility Study		6/21		10/30					
Requirements Review Meeting				10/30					
Finalize Requirements				10/30	1/8				
Phase I Recommendations / Phase II Proposal to DARPA					1/8				
Authorization to Proceed - Phase II					5/1				
Design and Development					5/1		12/10		
Preliminary Design Review						8/30			
Build and Test Prototypes						7/28		1/13	
Critical Design Review								1/21	
Deliverable Manufacturing & Burn-in							11/5		5/15
Systems Complete / Ready for Test								5/15	
Functional Testing								5/18-22	
Unit Training / Operational Field Experiments									10/5-28
Final Report									12/18

2.2 Program Milestones

Phase I Program Kickoff	21 June 96
Phase I Requirements Review	30 October 96
Phase II Overview	8 January 97
Preliminary Design Review	30 August 97
Critical Design Review	30 January 98
Initial Operational Experiment	18 May 98
Final Operational Experiment	19 October 98

2.3 Team Members Roles and Responsibilities

2.3.1 Government. The **Defense Advanced Research Projects Agency (DARPA)** was the funding agency and program management agency, and provided linkage for technology transition. **U.S. Army Soldier Systems Command** was the contracting agency, and provided day to day operational oversight of the contract; human factors design, engineering and testing; application selection, development and insertion; and system assessment and field test analysis. The **Office of Special Technology (OST)** served as the user representative, USSOCOM technology transition, and provided system proponent development. The **24th Special Tactics Squadron of the Air Force Special Operations Command (AFSOC)** provided user input into the hardware and software design, assisted in application development, and performed system evaluation and field experiment conduction.

2.3.2 Non-Government. **The Boeing Company** was the prime contractor and system supplier, and provided system design, integration and test. **American Megatrends Inc.** provided the motherboard circuit design, layout and production. **Tactical Technologies Inc. (TACTEC)** provided subject matter expertise in the application, served as the user technical interface, developed the keyboard concept, designed and built the vest garment, and assisted in the operational experiment. **Hughes Defense Communications** provided the radio communications interface and the MXF-610 remote control software. **Tulip Development Laboratories (TDL)** provided the detailed design and fabrication of the keyboard. **Seattle Sight Systems Inc.** provided the hand-held display units. **Kopin Corporation** provided the head mounted display units. **Ultralife Batteries Inc.** assisted in the battery design and produced and assembled the Lithium Ion Polymer battery packs.

2.3.3 Boeing Design Team Organization. The Boeing Design team consists of a Program Manager, a Principal Investigator and a team of senior level hardware and software design engineers. **Tom Runner** was the Program Manager; **Rodney Loyd**, the Principal Investigator; **Scott Schubert**, the Mechanical Design Engineer; **Sherry Price**, the Electrical Design Engineer; **Ike Slack**, Software Lead Engineer; **Mike O'Hara** and **Judit Jones**, Software Design Engineers.

2.4 Program Goals

The first phase of the program, a Feasibility Study, was conducted to establish the practicality and the potential utility of providing a wearable information system to the soldiers of the Special Operations Command. The primary goals of the program were to utilize DARPA pioneered wearable computer technology to enhance the capabilities of the soldier by providing improved situation awareness, streamlining access to needed information, reducing soldier workload by off-loading information management to the computer, and reducing voice traffic over field communications nets. These enhancements would provide decisive benefits to the soldier, by allowing his decisions to be based on better, more up-to-date information, reducing the time to locate needed information, reducing communications required to obtain information, and eliminating confusion due to over use of radio channels. Ultimately the use of the new information age wearable computer technology would result in more efficient and safer mission performance.

3.0 Results

This section describes the selected application for the SOCM system, the derived system requirements, and the resulting hardware and software which was developed on the program. Finally, the test and evaluation results are presented.

3.1 SOCM System Application

In order to demonstrate the potential and the utility of the wearable information system, it was desired to select an information intensive application which could benefit from the use of a body worn computer. The application was selected by DARPA, U.S. Army Soldier Systems Command and the Office of Special Technology, and would entail the use of wearable computers by combat controllers of the Air Force Special Operations Command to assist in information management during the Airfield Seizure Mission. This mission was selected because of its complexity, fast pace and highly information intensive nature, and could benefit greatly by improved information management, reduced soldier workload, and more efficient communications.

3.1.1 Mission Scenario. Boeing worked closely with personnel of the Air Force Special Operations Command to understand their information needs, their missions, and the mission environment. It was found that although the nature, environment and complexity of the missions varied greatly, there were certain primary information needs which were common, and that the use of wearable computers could potentially be of benefit. Reduced to the simplest level, these information needs are navigation, communications and battlefield information management.

In order to demonstrate the utility of the wearable system in a field environment, an information intensive mission scenario was selected as the technology testbed. The mission scenario would provide the application for the system, and would generate some of the low-level requirements for the system functionality.

The mission scenario selected was the airfield seizure mission, which is a short duration, highly information intensive mission. During such a mission, which is normally executed at night in hostile territory, the combat controller has many elements to mentally track. These elements include aircraft arrival / departure sequences, aircraft parking plans, personnel rosters and equipment. The controller is responsible for coordination of all movement of people or hardware about the airfield, and must direct a constant influx of air traffic arrivals and departures. During infiltration, aircraft are landing at the rate of one per minute, and with each arrival, more and more activity on and around the airfield occurs. This creates a highly chaotic environment where information access and management is the key to control of the situation.

3.1.2 Airfield Seizure Mission Information Needs. Six areas of information management needs were identified which seemed ideal for processing on the wearable computer system. These areas are mapping and navigation support, air traffic control support, communications, asset management, weather information, and call-for-fire support. It was proposed that during the design phase of the program, that demonstration software would be developed for each of the six areas, to demonstrate the potential benefits of

wearable computer system. The following provides a more detailed description of each area, and the desired capabilities to be demonstrated by the wearable system.

3.1.2.1 Maps and Navigation. Navigation is fundamental to survival in the battlefield environment. It is critically important for the soldier to know where he is, where his friends are and where the enemy is. The SOCM wearable computer would provide the capability to preload maps and diagrams of areas of interest, provided integrated GPS support, and enhance the soldiers ability to navigate by allowing waypoints, routes and reference points to be added on top of the background map. A moving map display was desired which would automatically center on the soldier's current position, which is fed into the program via the GPS. Therefore, software support for the GPS as well as an accurate PPS GPS receiver is required to be a part of the system.

3.1.2.2 Communications. Two aspects of communications were identified as mission needs by the users which were interviewed. One aspect is obviously the need to share digital information with other users in a field environment such as images, database files, and text messages. Digital communications capabilities for both short and long range communications were needed. For this program, the transmission of data over military radios and over commercial wireless LAN was desired, and could be of benefit in the battlefield environment.

The other aspect is the management of communications information such as callsigns, frequencies, nets and satellite locations. Prior to each mission, an enormous amount of this type of information must be memorized. Under the stress and chaos of a combat situation, the wearable can provide a memory backup for this information, thus reducing the risk of a soldier not having the critical information that he needs.

3.1.2.3 Air Traffic Control. Air traffic control information such as arrival / departure schedules, aircraft callsigns, parking plans, landing zone surveys, and aircraft specifications are all needed in the field environment. These are database type information files, and well suited for wearable computer use. Additionally, the software would be designed to provide the capability to dynamically sort the information, edit and facilitate replanning in the field, when schedule deviations occur due to unforeseen events.

3.1.2.4 Weather Information. Weather forecasts for various objectives and alternate objectives were desired, and could be preloaded on the system as text information.

3.1.2.5 Asset Management. During the missions, information regarding incoming cargo and personnel can be of great benefit. For example, if an incoming cargo aircraft is delayed or cancelled, it is necessary to know the cargo listing in order to assess the impact of the event to the mission, and allow for implementation of alternate plans for both cargo infil and exfil. This type of information is also well suited to the wearable system, and would be preloaded as mission information prior to the mission.

3.1.2.6 Call-For-Fire (CFF) Support. Another aspect to the special operations mission is the Call-For-Fire request, which can be initiated by the ground soldier in the event of a target encounter. To perform a CFF request, certain information must be radio broadcast in an exact manner and format. Many types of CFF formats exist, and because of the volume of information, it was found to be useful to provide a listing of the CFF formats as queue cards, and additionally, the ability to store pre-prepared CFF forms as well as providing the ability to dynamically record via keyboard entry new ones which are generated in the field.

3.2 System Requirements

During the Phase I feasibility study, the basic system requirements were established. In order to successfully operate in the Special Operations environment, the system needed to be rugged and environmentally protected, lightweight, cool and comfortable, and intuitive with a user friendly interface. The system should be low-power and provide a long runtime between battery recharges; a battery independent design would be even better. The system should allow hands free operation, but allow the use of an optional keyboard and mouse, and provide for the use of multiple display types. For security reasons, removable data storage is needed. The system should also offer compatibility with existing equipment, digital communications capability, and should have a short turn-around for mission setup. Producibility and affordability are also necessary for the system to eventually enter service in production quantities. Table 1 below summarizes the system requirements, along with the design approach used to ensure compliance.

Table 1. System Design Features

Requirement	Design Feature
Rugged, environmentally protected	Dust and sand tight, submersible in water to 3 ft., EMI shielded, -25C to 50C degree ambient operation, salt spray resistant, impact and vibration tolerant, and other environmental design considerations
Lightweight	System weight < 11 lbs.
Cool and comfortable	Garment uses modified mesh assault vest for light weight fabric and good air flow
Intuitive and user friendly interface	Software developed in close coordination with user to assure desired features and intuitive operation
Hands free operation	Head mounted display and voice activation allows hands free operation
Multiple display options	Helmet mounted, hand held and night vision displays offered as options
Optional mouse and keyboard	Rugged, miniature keyboard and mouse can be used if desired
Removable data storage	PCMCIA hard drive or flash card for mass storage
Interface with existing equipment	Compatible with PLGR GPS, standard radios (PRC-117, PRC-143), RS-232 can be adapted with PCMCIA card to MIL-STD-1553, J1708, ARINC-429 and others
Digital communications capability	Digital interface to standard military radios, radio remote control capability, high speed short range wireless Local Area Network
Producible and affordable	Motherboard and enclosure designed for production, automated test provisions allows unit cost at volume
Short mission setup time	Mission setup software will be provided for laptop or desktop to facilitate rapid mission information loading
Low power, long runtime between recharges, safe battery	6 Amp-hour non-explosive Li-Ion Polymer battery, 4 hour minimum runtime without power management (typ. > 5hr with power management), three power management modes, smart battery bus to provide battery health status to user

3.3 System Design

Working closely with DARPA, U.S. Army Soldier Systems Command, the Office of Special Technology and combat controllers from the Air Force Special Operations Command, the basic system configuration was defined. The System is shown in Figure 2 below.

3.3.1 System Components. The resulting system would consist of a vest mounted wearable computer, with helmet mounted and hand-held display units, a military GPS receiver, and a hand-held multi-band military radio. The primary mode of system control would be by voice command, but keyboard and mouse would be provided as auxiliary inputs for situations where voice was not appropriate, such as operations conducted in silence or in very high noise environments.

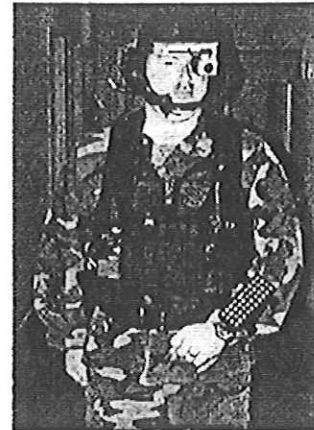


Figure 2. Soldier Shown Wearing the SOCM System

Table 2 below describes each of the primary system components:

Table 2. SOCM System Components

Component	Description
CPU Module	150Mhz Pentium CPU (upgradable to 200 and 233Mhz), 64MB RAM, Sealed Aluminum Enclosure
Vest	Cool, lightweight mesh assault vest with clip on pouches for CPU, GPS and Radio Interface Box
Keyboard	Arm mountable miniature keyboard with sealed keypad and backlighting
Mouse	Ruggedized sealed mouse assembly
Hand-held Display	640 x 480 Resolution black and white LCD display with integrated mouse control
Head-mounted Display	640 x 480 resolution black and white LCD display with integrated speaker and microphone
Lithium Ion Polymer Battery	6 Amp-hour (nominal) rugged and sealed battery pack
Wireless Local Area Network	1.5 Mbps short range wireless LAN card (Proxim RangeLAN2)
PRC-143 Radio	Handheld multi-band radio for digital communications
Hughes SP-TCIM Card	Tactical Communications Interface Module
Radio Interface Box	Provides voice / data switching for transmission
Cable Assembly Suite	Power Cable, GPS Cable, Display/mouse/keyboard Cable, SP-TCIM Cable and Radio Cable
Rockwell SOLGR GPS Unit	Most compact and robust handheld GPS receiver available (supplied on consignment by Rockwell)
System Software	Mission planning and setup software; SOCM Mission Software

All components are integrated into the vest garment to provide a complete man portable / man-wearable soldier information system.

3.3.2 System Weight. Because of the wearable aspect of the system, the weight and physical packaging of the components are extremely important. An aggressive weight budget was established for the design of less than eleven pounds for the basic system, and less than 16 pounds for the complete integrated system. The weight budget which was established at PDR and the final total system weight is show in the Tables 3 and 4 below for the basic and the fully integrated system:

Table 3. Weight Analysis for Basic SOCM System

Component:	Budget: (Lbs.)	Actual: (Lbs.)
CPU Module	3.15	2.84
Mouse	0.18	0.18
Keyboard	0.31	0.54
Cables (W1, W2, W3, W4)	1.39	0.96
SP-TCIM Card	0.08	0.06
Li-Ion Poly Battery Pack	1.70	1.95
Vest	2.50	2.56
Head Mounted Display	1.40	0.94
Wireless LAN Card and antenna	0.12	0.08
Total System Weight	10.83	10.11

Table 4. Weight Analysis for Fully Configured SOCM System

Component:	Actual Weight: (Lbs.)
Basic System	10.11
SOLGR GPS Unit	1.50
MXF-610 Radio	3.24
Radio Interface Box	0.90
Radio Cable (W8)	0.40
PTT Cable	0.36
Configured System Weight	16.51

3.3.3 System Power Consumption. Particular attention was given to the system power consumption. The processor and support chip set were selected in part because of advanced power management features. Table 5 shows the system power dissipation for the 150 and 233Mhz processors.

Table 5. System Power Dissipation

Component:	150Mhz Processor		233Mhz Processor	
	Max* (W)	Average** (W)	Max* (W)	Average* (W)
Motherboard	14.40	11.52	11.76	8.88
Display	2.28	2.28	2.28	2.28
Wireless LAN	0.47	0.47	0.47	0.47
SP-TCIM	0.40	0.40	0.40	0.40
Mouse	0.03	0.03	0.03	0.03
Keyboard	0.03	0.03	0.03	0.03
Total Power	17.61	14.73	14.97	12.09

* Power management disabled

**Power management enabled, W95 desktop displayed

Notice that by upgrading the Pentium processor from the 150Mhz to the 233Mhz, a 2.64 Watt reduction in power dissipation is achieved due to lower core CPU voltage requirements.

3.3.4 CPU Electrical Design. The heart of the system is the Central Processor Unit (CPU) assembly, which was designed to be rugged, lightweight and small, but also to be a very powerful state of the art computer for a body worn platform. The CPU is a 150MHz Pentium MMX single board computer, (upgradable to 200 and 233MHz), with 64 Megabytes of RAM, 2 Megabytes of Video RAM, a 340 Megabyte PC Card ATA Hard drive plus three other PCMCIA slots. The SOCM motherboard is shown below in Figure 3.

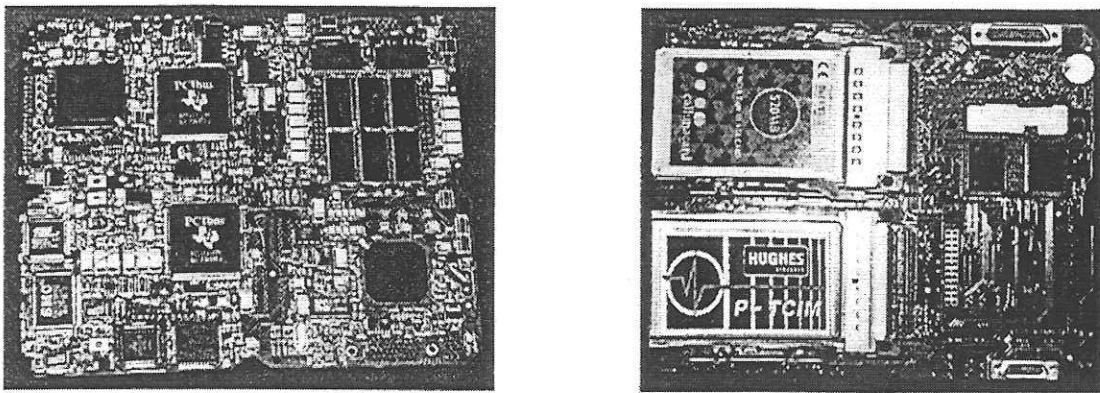


Figure 3. SOCM Motherboard Assembly, bottom side shown at left and top side on right

The system provides outputs for Super VGA video, keyboard, mouse, microphone and speaker, two serial ports and universal serial bus, as well as +5 and +12 volt output power for peripherals and control signals. The system motherboard design also allows the substitution of an IDE hard drive in place of one of the dual PCMCIA card stacks, which can be accomplished at time of the board build. Overall, the system performance and specifications are the equivalent of many desktop computer systems, but innovatively packaged to meet the needs of a Special Operations soldier in a field environment. The Specifications and features of the CPU and motherboard design are shown in Table 6, below:

Table 6. Motherboard Specifications and Design Features

SOCM Motherboard Specifications	Motherboard Design Features
Intel 150 Mhz MMX P55C mobile processor	Multi-chip Module processor for minimal footprint
Intel 430 TX (Mobile Triton III) chip set	Plug in upgrade to 200 and 233 MHz MMX
Integral 320MB Hard Drive	Dynamic System Power Management
64 Megabytes Dynamic RAM	Accepts ATA flash card mass storage
16 Bit Sound Blaster compatible stereo sound	Low Battery indicator (yellow)
Super VGA driver with 2 Mbytes on board VRAM	High (red) and Low (green) temperature indicators
3 PC Card Slots (2 Type II, 1 Type III) plus HDD Slot	Temperature sensor and board heater control switch controls
SMBus for battery health status	Two connector interface to enclosure harness
Two RS-232 ports	Provisions for 2.5" IDE hard Drive (up to 2.1 Gbytes)
One Universal Serial Bus (port)	Input circuit protection
+5VDC and +12VDC auxiliary power outputs	

3.3.4.1 Microprocessor Selection. The microprocessor selection was based on previous design studies performed on the MARSS contract which identified the Intel Pentium processor as the logical choice to offer maximum performance and compatibility. At the time of the design baseline, the Intel 150Mhz processor was the state of the art processor, and speeds of 200 and 233MHz were anticipated for future releases. To support the processor, the Intel Mobile Triton III (430TX) chip set was chosen as the latest generation components available, and because of the advanced power management features and guaranteed compatibility with future processor upgrades.

To achieve maximum reduction of board area, the use of multi-chip modules for the processor and support chipset was explored. Two companies surfaced as possible suppliers of the needed components: MicroModule Systems, which had previously produced a MCM (called the Gemini Module) using a Pentium P54C 90Mhz processor, and PicoPower Vesuvius Chipset, and Fujitsu, which had recently announced the release of their new MCM, containing the latest Pentium processor, the 150MHz P55C, and Intel's 430TX support chipset. In the end, product availability and commitment to produce resulted in the selection of the Fujitsu module. The selected MCM replaced 93 motherboard components, including the Pentium processor, 430TX PCIsset, 256K of Level 2 Cache memory, temperature sensor, and various passives. The total board surface area used by the MCM was only three square inches.

3.3.4.2 Mass Storage Device Selection. To provide the system with adequate mass storage was quite a challenge. Essentially three options were available to meet this need: Rotating IDE Hard Drives (commonly used in Notebook computers), Rotating PCMCIA hard drives (adding the convenience of removeability), and PCMCIA Flash memory, which is much more rugged, but more expensive and only available in relatively low storage sizes. A trade off was made of each option, and the results were presented to the users and the customer. A comparison of the storage devices considered is shown below in Table 7.

Table 7. Mass Storage Device Comparison

Characteristics	IDE 2.5" Toshiba	Flash SanDisk	Flash SanDisk	PCMCIA Calluna
Removable	No	Yes	Yes	Yes
Storage Capacity	2.16 GB	110/220 MB	300 MB	520 MB
Data Transfer Rate (MB/s)	16.6	3.0	8	6.39
Operating Vibration (G)	0.5	15 pk to pk max.	15 pk to pk max.	-
Non-operating Vibration (G)	-	15 pk to pk max.	15 pk to pk max.	-
Operating Shock (G)	100	1000	1000	200
Non-operating Shock (G)	200	1000	1000	750
Weight (oz)	5.5	3.2	3.2	2.7
Operating Temperature (C)	+5 to +55	-40 to +85	-40 to +85	0 to +55
Storage Temperature (C)	-20 to +60	-50 to +100	-50 to +100	-40 to +70
Cost* (\$)	285	2129 / 4605	4400 est.	600

* cost at time of study, approx 6/97

Because of the application to Special Operations, security requirements dictated the necessity to be able to remove the drive from the computer. The Calluna 520Mb PCMCIA drive was selected as the drive of choice. To add versatility to the motherboard design, the layout was performed in such a manner that the PCMCIA drive could be removed and replaced with a 2.5" IDE drive with merely a connector swap. This provided the ability to broaden the application of the system to uses which required the larger hard drive, such as Maintenance & Logistics, where the storage of large files such as Electronic Technical Manuals is desired.

Following the completion of the prototype SOCM motherboard, a problem was discovered in using the Calluna 520MB drives as a bootable device. An investigation of the problem by Boeing, Calluna and American Megatrends resulted in the conclusion that there was an apparent incompatibility between the Intel PIIX4 chip on the motherboard and the Calluna drive. Other drives tested including the Integral 340MB and SanDisk 85MB flash memory card worked as bootable drives, therefore, an alternate drive was selected, the Integral 340MB PCMCIA drive. This drive has worked quite well in subsequent system tests, but because of the small size it precluded the use of the advanced power management functions, which required 70MB of free disk space to be allocated for suspend / resume functions.

3.3.4.3 Power Management. The SOCM system incorporates the Intel 430TX Mobile Triton III chipset which provides power management to allow maximum battery life while maintaining enough performance capabilities to execute user applications with minimum degradation.

3.3.4.4 Description of Power Management States. The PIIX4, PCI to -ISA IDE accelerator manages processor transitions between the three power management states. The three main states for power management are the Standby, STR (Suspend To RAM) and STD (Suspend To Disk) states.

a.) Standby. When the operating system, application program, or system software is not doing useful work, the CPU complex, including the CPU, DRAM, L2 cache and peripherals that support doze do not have to execute cycles and therefore can be placed in Standby mode.

In the SOCM design, CPU standby is achieved by effectively throttling the CPU clock. CPU clock throttling is a user controlled function, through the AMIBIOS Power Management section. Clock throttling includes placing CPU in Auto-Doze mode where the CPU Clock is throttled using the STPCLK# signal. Local Peripheral Auto-Doze is attainable for devices that support the PCI Stop Clock mechanism as defined in the PCI Local Bus Specification Version 2.1. Under this interface supporting devices get a CLKRUN# signal indication from the PIIX4 telling them when to shut off their clock inputs, thereby achieving a doze state similar to that of the CPU.

Once the Auto Doze feature is enabled through the AMI BIOS Setup, the system enters and exits this state without user intervention. For example, the system may enter and exit Auto Doze mode in between keyboard keystrokes, mouse movements, etc. This feature utilizes the fact that the user input is necessarily staggered in the time domain.

b.) Suspend-to-RAM. (STR). Unlike the Standby State where the power savings are achieved by controlling the clock, this mode shuts off the CPU and some local devices completely by removing power. Since power is to be removed, AMI BIOS first saves the entire CPU and peripheral context in the system RAM before entering this state.

STR can be defined in the AMI BIOS Setup screen by defining the amount of time before the system is allowed to enter STR. This time is kept in a continuous global counter that reloads every time there is a system event such as a keyboard input or mouse movement. If there is no system activity for the time defined by the user, then the system will save all context in system RAM and switch off power to CPU, Chipset, PCI components etc. The only portion of the chipset that is kept alive is the "resume-well" that performs the suspend-memory-refresh and also monitors the Suspend/Resume button.

The user can enter the STR state due to the expiration of the timer, as defined above, or by pressing the Suspend/Resume button. The user can exit this state ONLY by pressing the Suspend/Resume button.

c.) Suspend to Disk (STD). Suspend to Disk is the state that saves the maximum amount of power. There are two different ways to setup the SOCM unit to enter the STD state:

First, the user can define the Suspend State in the system BIOS to STD and define the time that the system must wait before entering STD. This will cause the system to wait

for the defined amount of time and then enter the STD state. The second method is for the use to define the Suspend Mode in the system BIOS to AUTO, then define the suspend to RAM (STR) time, then the suspend to disk (STD) time. Using this method, there are two separate timers being defined. The first timer will take the system to STR, then the second timer will transition the system from STR to STD.

As the name suggests, STD copies the entire system context onto the hard disk. Once the context is copied, ALL system power supplies (including the RAM) are turned off. In this state only about 6mA are used to monitor the Suspend/Resume button. This state can be entered either automatically (on expiration of the timer) or immediately by pressing the Suspend/Resume button.

The system can be restored either by cycling the Power Button OR through the Suspend/Resume button. In either case, the system goes through the BIOS post sequence, as it would for a regular power-on, but before booting to Windows95, the system will restore the system state so that the user is back to the exact point where the system entered the STD.

3.3.5 CPU Mechanical Design. To protect the electronics from damage due to handling and the environment, the motherboard is housed inside a black anodized machined aluminum enclosure which provides a rugged, sealed and EMI protected housing. The CPU is completely sealed from the outside environment using a conductive rubber O-ring seal between the cover and enclosure, as well as incorporating sealed switches and connectors. The PCMCIA card slots are accessible by removing the sealed covers on the end of the CPU assembly, which also provide O-ring seals. I/O from the PCMCIA cards are sealed using sealed bulkhead type connectors for signal pass through, which are mounted in the PCMCIA access covers. Low Battery, High and Low Temperature indicator lamps and the Power and Suspend/Resume switches are located on the top surface of the unit. The board is rigidly attached to the inside of the enclosure, and cabled to the bulkhead using an internal wiring harness. Various points on the board are vibration damped using elastic foam padding, to minimize the shock and vibration that is translated from the enclosure surface to the electronics. The SOCM CPU enclosure assembly is shown in Figure 4.

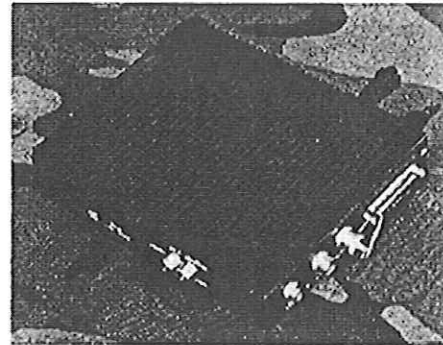


Figure 4. SOCM CPU Assembly Enclosure

3.3.5.1 Environmental Design Goals. Although the system was not designed to a specification, certain environmental design goals were established. The environmental performance goals for the system are shown below in Table 8.

Table 8. Environmental Performance Goals

Attribute	Performance Goal
Operational Temperature	-25C to +50C
Storage Temperature	-40C to +85C
Humidity	95% Noncondensing
Vibration	5 to 55Hz sinusoidal
Shock	40g, 6-9ms, 18 pulses
Submergence	One hour in 3 feet of water
Altitude	40,000 ft, unpressurized aircraft cabin
Salt Spray	48 hour exposure in 5% salt spray solution
EMI Emissions / Susceptibility	Emissions RE-01, -02 Susceptibility RS-01, -02, -03
Dust and Sand Exposure	Mil-T-28800D
Nuclear, Biological and Chemical (NBC)	Army Regulation 70-71

3.3.5.2 Thermal Design. The cooling for the system is entirely passive, with the heat from the hotter components being conducted directly into the enclosure, where it is convected into the environment through the fin design on the front of the unit. A number of different methods were analyzed for impact on thermal performance of the system. Some of the methods examined included surface area analysis, modifying the circuit board material to a thermally conductive material, increasing the copper trace thickness, and exploring the use of different methods for achieving a good conduction path from the hottest components to the case.

The final thermal design consists of an all-aluminum enclosure with the surface area and heat fins optimized for maximum heat transfer. Heat produced by the components on the motherboard is transferred to the enclosure walls via conduction, radiation and to a lesser degree, natural convection. Heat from the higher powered components such as the multi-chip module and the DRAM are conducted directly to the enclosure walls using Thermagon brand highly conformable thermally conductive elastomer. This material has a very high thermal conductivity for maximum heat transfer, while being very soft to provide excellent shock and vibration isolation for the components. The pads are mounted in two locations to provide a direct thermal path from the components to the enclosure: one path is directly from the Pentium processor (by far the hottest component) to the enclosure front, and the other is from the DRAM to the enclosure back. The front surface of the unit contains heat fins, to dissipate the heat to the environment and away from the user's body, and the vest design provides a mesh cover over the CPU to improve airflow and heat dissipation properties around the CPU.

Three methods of analysis were used to verify the design prior to constructing the prototype: hand calculations, Sauna thermal analysis software and the construction of a Thermal Mockup unit. The analysis predicted a delta T of 19.9C between the case and the ambient air, and a delta T of 35.7C between the inside air and the ambient air. This was verified experimentally, and was within 1.3C. As shown in Figure 5 below, it can be seen that the inside and outside case temperature stabilizes after approximately 60 minutes.

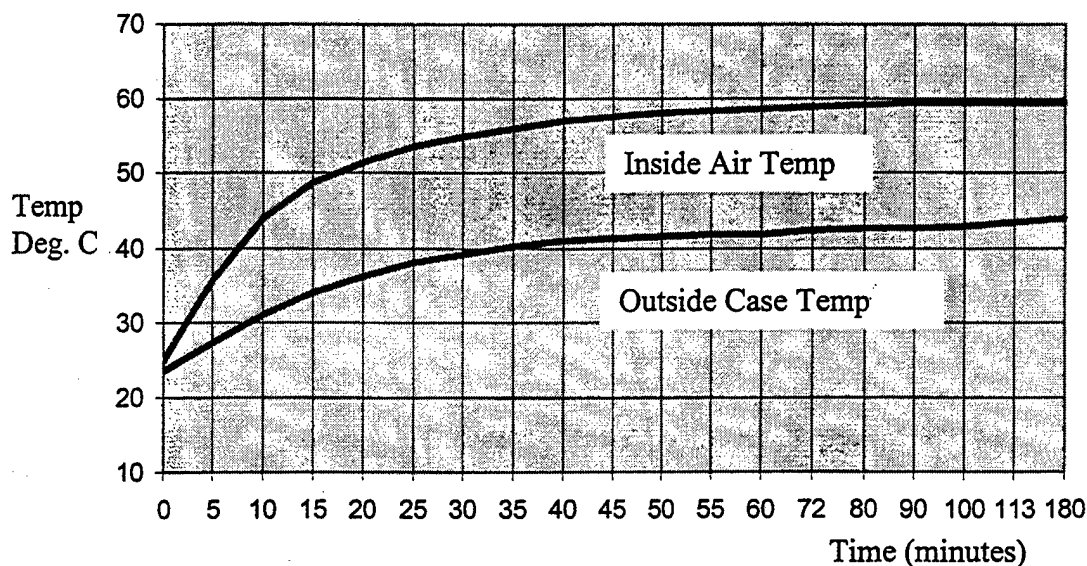


Figure 5. Thermal Analysis Results

The thermal analysis has predicted that the system will successfully operate at the maximum rated temperature of 50C, as shown in Table 9 below.

Table 9. Thermal Analysis Results at 50C Ambient

Parameter	Predicted Temp	Max Rated Temp
Tcase	68.6C	-
Tmcm	86.6C	85C
Tvideo chip	73.4C	70C
Tdram	72.6C	70C

3.3.5.3 CPU Heater Performance and Operation. For operation in cold temperature environments, an internal heater is provided to pre-heat the electronics to their minimum rated operating temperatures for boot-up. Once the system is up and running, the self-heating of the components is adequate to keep the system running, and the heater is disabled to conserve battery power. To implement the heater design, temperature sensing and switching circuitry is installed on the motherboard, and a Minco Thermofoil Heater is mounted inside the CPU.

Analysis was performed to determine the most efficient type of heater to heat the CPU electronics, and the heater was then installed and tested inside the CPU thermal mockup to verify theoretical calculations. The goal was to raise the internal CPU temperature from -25C to +5C in approximately 15 minutes. To increase the internal temperature by the required delta T of 30C, it was determined to require 39Watts for 15.5 minutes. This

would impose a 13% drain on the total battery capacity (based on a 6 Amp-hour Lithium Ion Polymer battery).

3.3.6 Battery Design. A battery was sought for the system which could provide high power density, long system runtime and which was safe to carry or wear on the human body. By leveraging work from the MARSS program, the battery technology selected was the Lithium Ion Polymer solid electrolyte batteries produced by Ultralife Batteries Inc. To improve the durability over the MARSS batteries, the battery design was changed from the flat flexible battery worn on the back to a brick design, enclosed in a 6.5" x 4.5" x 1.25" thermal plastic rigid case which could be worn on the belt. The new battery design would utilize the improved chemistry 1.55 Amp-hour Lithium-Ion Polymer cells, packaged in a 4 x 3 cell arrangement to provide 6 Amp-hours at 11.4Volts. The battery weight is 1.95 Lbs., and was designed to power the system for a minimum of 4 hours. The battery also contained a SMBus compliant charge management circuit to control the charge and discharge cycles preventing over-voltage during charge, and under-voltage during discharge. The Lithium-Ion Polymer battery pack is shown below in Figure 6.

Many improvements in performance were seen over the initial MARSS Lithium Ion Polymer batteries. However due to production difficulties, the batteries were still assembled by hand, and proved to be unreliable over time. The battery capacity faded on three of the four units to approximately 50%, after 6 months of use. As an alternative to the experimental polymer battery backs, Boeing also provided an additional set of rechargeable 4 Amp-hour commercial Lithium Ion batteries which would power the system for approximately 2.5 hours. Because the system was designed to be essentially battery independent, the military issue BA-5590 primary lithium batteries were also used during the system evaluation, and proved to be very reliable, and would power the system for in access or ten hours.

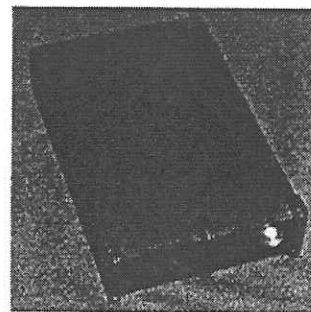


Figure 6. Lithium-Ion Polymer Battery Pack

3.3.7 Display Systems. The display requirements of the Special Operations soldiers were analyzed during the Phase I feasibility study, and the conclusion was that three display configurations were needed, depending on the exact usage. For example, some operators did not prefer to have a device mounted on their heads at all, while others desired the displays to be integrated with their night vision systems. The three main configurations identified were (1) Night vision system with integrated display, (2) Day/Night headmounted display and (3) Day/Night handheld display. To ultimately satisfy the environmental requirements, it was also established that the display technology should be Electroluminescent, and that a number of other factors should be considered in the design such as minimizing light emissions, providing a brightness control (to allow nighttime viewing), and consideration of overall environmental protection.

A display was desired for the SOCM wearable computer that could provide a high-resolution, high quality image, similar to a desktop monitor but in a compact form factor that could be easily carried or worn by a completely mobile soldier. Two candidate technologies emerged as possible contenders for this system: the Active Matrix Liquid Crystal Display (AMLCD), and the Active Matrix Electroluminescent (AMEL) display. These technologies were developed by DARPA beginning in 1991 on the Head-mounted Display (HMD) program managed by Dick Urban of DARPA and Henry Girolamo of U.S. Army Solder Systems Command. Today both technologies are available in head-mounted display systems for both the military and commercial markets. The AMLCD and AMEL technologies have their advantages and disadvantages, and selection of one over the other is most likely dictated by the application. AMLCD currently provides the best image quality, requires simpler drive electronics and is presently available in monochrome, black and white and full color. On the downside, AMLCD is a non-emissive device (i.e. does not generate its own light) and thus requires a backlighting source. At low temperatures, the liquid crystal will freeze, limiting the operating temperature of the display or requiring an internal heater. AMEL on the other hand is an emissive device, so no backlighting is required. It delivers a very crisp and high quality image, and allows a wider viewing angle than does AMLCD. It is also very rugged, long life and has a wide operating temperature range, making it more suitable for the military operating environment. Unfortunately the drive scheme is somewhat inefficient causing the drive electronics to be larger and more complex.

Early in the program, a market survey of head-mounted and hand-held display systems was conducted and the results are shown in Table 10.

Table 10. Display Systems Evaluated for use on the Special Operations Combat Management System

Manufacturer	Form Factor	Type	Color	Resolution	Power	Temp. Range
Honeywell	Helmet Mounted	AMEL	Amber	640x480	4W	-32C to +49C
Kopin	Head / Helmet Mounted	AMLCD	B & W	640x480	3W	0C to +55C
Seattle Sight Systems	Head / Helmet Mounted	AMLCD	B & W	640x480	3W	0C to +60C
Kaiser	Head Mounted	AMLCD	Color	640x480	3.5W	0C to +55C
Seattle Sight Systems	Hand Held	AMLCD	B & W	640x480	3W	0C to +60C

Only one system was found that would withstand the military environmental factors, and that system was the Honeywell day display being developed for the Land Warrior program. Unfortunately, the display availability schedule did not align with the SOCM program, and alternate display systems had to be selected. The other display systems were all of commercial quality, and provided adequate image quality for displaying the required information. A common problem with all of the display units is the limited field of view, which makes it difficult to view wide area images such as maps. This is the

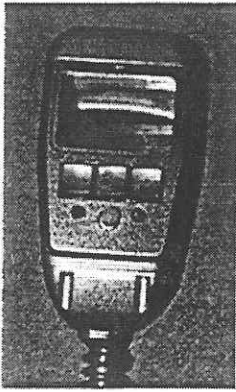


Figure 7. Hand-held display unit

same problem that is exhibited on desktop systems when a large area image is viewed on a small monitor. There is just no electronic substitution for the orientation and peripheral visual cues of folding a large paper map out on the tabletop.

For demonstration on the SOCM program, both a hand-held display and a head-mounted display was selected. The hand-held display would be the Seattle Sight Systems Mark II HH display shown in Figure 7, as the only hand-held unit available without development costs. The Kopin Explorer Head Mounted Display, shown in Figure 8, was selected as the helmet mounted system, and was easily

mounted on the Integrated Ballistic Helmet used by the user. The Seattle Sight Systems helmet display had a slightly smaller field of view, but was preferred by the user and was selected on a follow-on program for additional SOCM computer systems.

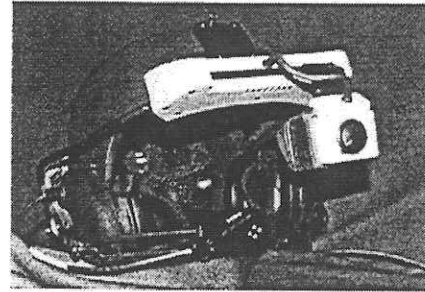


Figure 8. Head mounted display installed on the IBH

3.3.7.1 Night Vision Integrated Displays. At the outset of the program, one consideration in choosing a display system was how would the display interact with the soldiers existing night vision systems. For this particular application, the combat controllers frequently operate with night vision equipment, typically the AN/PVS-7 or the AN/AVS-6 night vision goggles. Night vision compatibility was investigated over the course of the program, and it was found that in order to view any of the commercially available head-mounted or hand-held displays, the user would be required to move his night-vision equipment away from his eyes. None of the above displays are designed for direct viewing with night vision equipment, but with proper filtering, it could be achieved.

At present, Honeywell Inc., Military Avionics Division is working on a night vision integrated display system for the dismounted soldier, the night vision display for the Land Warrior program. This system will incorporate a 640x480 AMEL display into the PVS-14 night vision tube, and will become an element of the Land Warrior Integrated Helmet Assembly Subsystem (IHAS). This system seems ideal for use with the SOCM system given the current user, but was investigated as an element of the SOCM system, and found that the availability schedule of the Honeywell night vision display did not support the delivery of the SOCM systems. The Honeywell system may provide a future solution to the issue of integrated night vision with the computer display.

3.3.8 Keyboard. Under certain circumstances, the users expressed the desire to have a keyboard for the input of information. Early in the study phase of the program, it was anticipated that an off the shelf unit could be found that would provide a small but rugged keyboard suitable for military use. After an extensive market search, no suitable keyboards were found. A number of wrist and arm mount keyboards were located, but

all were of commercial quality, similar in design and construction to a -calculator keyboard. This presented problems not only in durability, but in being able to read the keyboard and to use it with a gloved hand. The design team determined that the only way to provide a high quality militarized miniature keyboard was to do a custom design.

The resulting product is a 39-key lightweight, sealed and backlit keyboard, (shown below in Figure 9) which is strapped onto the forearm of the soldier. To minimize the size, each key is three-functioned, and only essential keys are included; but the individual keys are kept large, (.4" square) to permit operation with the gloved hand. The unit was designed with a clamshell style black anodized aluminum housing. Each key is guarded with a bezel to protect from inadvertent hits. The keypad is a one-piece rubber elastomer, which seals out dirt and water. Backlighting is provided individually under each key, but must be turned on manually, to protect from light emissions when operating in black-out. Ten levels of backlighting brightness are provided. The keyboard is a high quality unit, with a rugged look and feel, which further complements the military look and feel of the overall system.

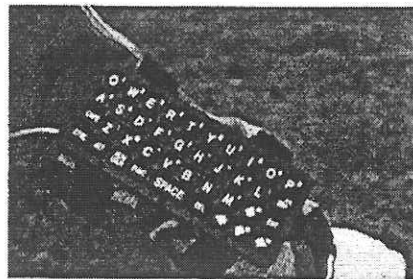


Figure 9. Keyboard Assembly

3.3.9 Vest Garment. The Vest Garment was designed and built by Tactec Inc, with careful consideration being paid to comfort, equipment placement, safety and utility. The vest garment was designed to provide a very tightly integrated on-body packaging approach for the suite of electronics as shown in Figure 10. The garment consists of a mesh assault style fabric (chosen for airflow and cooling), with a front pouch to house the Central Processor Unit (CPU) assembly, and side pockets to hold the system battery and the GPS receiver. The radio is either belt worn, or carried in the rucksack, which is a typical location for radios currently carried by the Special Operations soldiers. Lace up sides in the vest garment allow for the system to be worn close to the body, or loosened to wear on top of other equipment such as body armor. The system cabling is also buried within the vest garment, and is routed in hidden channels to minimize the obtrusiveness of the equipment interconnects. Care was taken to avoid routing cables across the front zipper, and quick release latches are incorporated to allow the user a rapid method for shedding the system in the event of an emergency. When worn on the body, the vest and equipment are well balanced and the weight is evenly distributed to provide a conformable and mobile body worn computing platform.



Figure 10. SOCМ Vest

3.3.10 Digital Communications. To implement the communications needed for the system, a two-tier architecture was chosen. First, the system takes advantage of

commercial off the shelf wireless LAN technology, which provides a 1.5Mbps wireless network connection, and allows multiple users of the SOCM system to be on the network at separation distances of up to 1000 feet. The use of network access points and repeaters stations can further increase the range, and allow a high degree of flexibility in defining the coverage area. For long range communications, the Hughes AN/PRC-143 hand-held multi-band radio provides a slower but longer range digital communications link to other SOCM users, as well as non-SOCM users operating with a compatible radio. For extended range and secure communications, the system is also compatible with the AN/PRC-117 manpack radio, allowing secure data transfer at rates up to 16Kbps.

3.3.11 GPS. Many possible solutions were considered for the GPS element of the system. Some of the possibilities included using commercial-off-the-shelf PCMCIA GPS cards, designing a custom module with a Rockwell GPS engine, and using a standard GPS solution such as the Precision Lightweight GPS Receiver (PLGR). It was determined that a PPS (military accurate) GPS solution was required, which ruled out the PCMCIA GPS solution. A custom GPS module design was also abandoned, due to the upcoming availability of a new GPS, Rockwell's Special Operations Lightweight GPS Receiver (SOLGR), shown below in Figure 11. The SOLGR is a smaller and lighter "next generation" GPS, designed specially for Special Operations use. The unit provides serial ports, which allow connection to the SOCM computer, and an external antenna connector. Therefore, the SOLGR was selected as the GPS solution for the program.



Figure 11.
SOLGR GPS

3.3.12 System Software. The SOCM system software was developed to support a particular mission scenario, the airfield seizure mission. During the initial feasibility study and throughout the development program, AFSOC combat controllers were interviewed and the specific mission information needs to support the mission were identified and incorporated into the software. Essentially there were three main functions of the software: Navigation and geolocation, Mission Database support, and communications. Additionally, a mission setup software module was developed to facilitate preparation of the wearable system of the mission. The mission setup module is executed on a laptop or desktop computer, configures the source mission data and provides automates the loading process for the wearable hard drive.

3.3.12.1 Navigation and Geolocation. A moving map display was desired which could support maps in standard NIMA formats, incorporate GPS information, and provide the capability for tactical overlays to be shown on the map. Numerous off the shelf and custom options were explored for providing the needed mapping and navigation capabilities. In the end, an off the shelf package called Vista was selected. Vista provides moving map capabilities, GPS position and tracking functions, as well as zoom in / zoom out and other user features. To use Vista with NIMA maps, a importer utility called DMAMUSE Raster Importer is used to convert the maps in the mission setup software.

An additional map viewing utility called ACDSsee is provided which will enable the viewing of maps provided in other common graphics format. This can include scanned in maps, sketches, diagrams, etc.

3.3.12.2 Mission Database Support. To allow easy access to specific mission information, a number of database type files are supported. The mission data is supplied electronically by the user, and is loaded onto the hard drives during the mission setup. Table 11 shows Mission databases which are supported:

Table 11. Supported Mission Data

Aircraft Information
Arrival / Departure sequence
Airfield Diagrams
Survey Forms
Extended Aircraft Information
Asset Management Support
Passenger Manifest
Load Plan
Execution Checklist
Call Sign Matrix
Communication Grid
CEOI
Satellite Communications Matrix
Weather Information
Call-for-fire Forms

Each database can be displayed in tabular form, and features are provided to facilitate sorting, editing and viewing the data. Additionally a utility is supplied to calculate Satcom antenna aiming angles.

3.3.12.3 Communications. The mission software also allows data files to be transferred using both the Wireless LAN and the military radio methods. Two radios are supported, the PRC-143 multiband handheld radio, and the PRC-117, a multiband manpack radio. In order to control the radios, a radio setup menu is provided, which allows the user to specify the channels, bit rate, modulation, error correction, and specify the number of radios to be used.

3.3.12.4 Mission Setup. To facilitate preparing the SOCM systems for a mission, a Mission Setup Software module is provided. The software is executed on a laptop or desktop computer, and prompts the user to insert disks or CD's containing the source information. When mission setup is executed, the following steps are performed in setting up the hard drives.

1. Clear previous mission data (from setup module)
2. Load DMA Maps
3. Load Other Maps
4. Load Air Traffic Control Data

5. Load Asset Management Data
6. Load Communications Data
7. Load Weather Data
8. Load Graphics Data
9. Setup GPS
10. Setup Radio Channels
11. Load SOCM Hard Drives

When mission setup is completed, the user transfers the data to the SOCM hard drives either by plugging the hard drive into the laptop PCMCIA port, or by using the wireless LAN.

3.4 Test and Evaluation

The test and evaluation for the SOCM system was performed in two phases. First, an initial OT&E was performed at Boeing in Huntsville during May '98, with participation of TACTEC and the 24th STS, to establish that the hardware and software was functionally operational. Then a follow-on Operational Field Experiment was conducted in October '98 by TACTEC and the 24th STS, by actually deploying the SOCM units on an operational exercise.

3.4.1 Initial Operational Test & Evaluation. Initial functional testing of the SOCM systems took place at the Boeing Jetplex facility in Huntsville, Alabama during the week of May 18 – 22. The testing was conducted jointly between Boeing, TACTEC and a member of the 24th STS of USAFSOC. The first day of the activity consisted of equipment familiarization, and a walk-through of the test procedure. The test procedure does not perform an exhaustive test, but is designed to provide a step-by-step checkout of all of the major functions provided on the SOCM. The test procedure consisted of a step-by-step instruction list of how to access and use all of the mission information loaded onto the systems, and how to utilize the wireless LAN, radio communications and the GPS functions. By the second day, the test procedure walk-through was completed. Prior to beginning the formal testing, the mission setup software was demonstrated to show how a system would be loaded for a mission from scratch. The mission setup software runs on a laptop, and allows mission data to be loaded from Compact Disk, Floppy Disk or PCMCIA hard drive. An on-screen step-by-step procedure is followed which prompts the user to load each type of data (weather, maps, airfield diagrams, etc.), and then the mission setup software copies the data to the SOCM hard drives.

Beginning on day three, the formal run of the test procedure was initiated. Most sections of the test procedure went smoothly. The comfort of the system and the Head-Mounted Display was very good. Even after wearing the systems for several hours in 90+ degree temperatures and high humidity the systems worked fine, and produced very little discomfort due to heat. The mesh design allowed good airflow and kept the users reasonably comfortable.

Overall, the hardware and software for the SOCM systems worked reasonably well as designed, with the exception of the file transfer function over the PRC-143 Radios. The

reliability of the data transmissions was poor, and when more than two radios attempted to network into the system, virtually all communications over these radios were lost. Because of the difficulties encountered, this portion of the experiment was scrapped, and it was agreed that the radio performance would be investigated separately following the conclusion of the experiment.

Following the testing, a test report was prepared and submitted with the May '98 Monthly Technical Report, documenting in detail the proceedings and findings of the testing. A list of software discrepancies was generated, and all items were corrected prior to the shipment of the SOCM systems to Ft. Bragg for the Operational Experiment.

Between May 25 and June 12, additional investigation of the radio communications issues was conducted, looking at both the prototype PRC-143 radios and the fielded PRC-117's. This investigation concluded that the PRC-143 radio in its current state of maturity is not a suitable radio to be fielded for the purpose of digital communications, and that better and more reliable results can be achieved by using the PRC-117 digital radio, which is already fielded with the 24th STS. The PRC-117 can provide more reliable transmission when operating in analog mode (AFSK), and when keyed with a crypto code, the radio can be used digitally to provide much faster data rates, up to 16Kbps, as opposed to only 300-400 bps which was observed on the PRC-143. The radio issue was discussed with system users in the 24th STS, and they felt that using the PRC-117 radio, which is a radio that they carry anyway, was a good solution to the digital communication problem, and provided advantages in system familiarity, data transmission rates, and known reliability.

3.4.2 Operational Field Experiment. To accomplish the Operational Field Experiment, four SOCM systems were deployed with the 24th Special Tactics Squadron during a Joint Army and Air Force exercise involving tactical airfield operations from 12-28 October 1998. Planning and rehearsals were done at McChord AFB, Washington, but the actual tactical airfield used for the mission was located in another state. This exercise included Army/Air Force aviation assets, army ground troops and Air Force Special Tactics personnel. During 5 - 16 October 1998, prior to the mission deployment, classroom and field training was conducted at TACTEC's facility in Hope Mills, North Carolina, to familiarize the mission participants with the operation and use of the SOCM Systems.

Mission information was developed and transferred to the software of three SOCM systems. The fourth system was used as a spare. These three systems were readied for use but only one was used in a limited capacity during the tactical exercise. The one SOCM system employed was worn by TSgt. Dickson. TSgt. Dickson was assigned an administrative position at the air traffic control point and used the SOCM as an information management tool. His test consisted mostly of using the software and displays to track mission data and events such as execution checklist calls, communications call signs and frequencies, parking plans, aircraft arrival/departure sequences, and personnel manifests. Early on during mission planning the PRC-117 radios were tested with the system but could not be made to work with the software. The LAN worked very well and was used to transfer mission data from the laptop computer to

the SOCM systems. Since only one person with a SOCM was allowed on the airfield the LAN was not tested nor used. Furthermore, the 24 STS had decided that because the LAN was not a secure means of communications it would not be used.

By far, the greatest challenge experienced in the utilization of the SOCM systems for an actual military exercise was getting the abundance of ever-changing mission information loaded onto the systems. Although a mission setup utility was provided on a laptop to expedite this process, the strict controls of the formats of the source information was not in place, nor was it anticipated that the information would be changing continually until the deployment began. If it were not for tremendous efforts and diligence of Les Wolfe of TACTEC and Sgt. Eric Vollmer in getting the system information loaded, the systems would not have made the deployment. Much was learned during the preparation phase about the rapid operations tempo, and the dynamic nature of mission information that would certainly influence the design of future generations of the mission software.

During the exercise, TSgt. Dixon used the system to manage and access information and to provide it to the team leader. The system worked effectively in this capacity, but he questioned whether in its current form if it was any more effective than the manual way of paper, memory and grease pencil. TSgt. Dixon stated that the map program with the GPS was very informative, and has a lot of value in urban Call-For-Fire. Problems were experienced, however, in the digital communications areas; because of security issues, the wireless LANs were not used during the exercise, nor were the PRC-143 or PRC-117 radios, because of functional and operational difficulties. The vest itself was comfortable, but did pose some interference problems when worn with the other required equipment. TSgt. Dixon commented that the use of the head mounted display was not very practical in a tactical situation, and an integrated display into the Night Vision Goggle would be much more desirable.

Overall, although some problems were experienced, as one would expect with any prototype system, TSgt. Dixon stated that there were many aspects of the vest that were not tested that may be useful to the airfield environment and that he could see the future potential of the system in the Special Operations Community.

Following the Operational Experiment, a complete Training, Field Test and Evaluation Report was prepared and submitted by TACTEC, which documents in detail the events of the testing, the After Action Reports, Hardware and Software Component Evaluations, and the results of the User Surveys.

3.4.3 User Survey Results. In order to quantitatively document the results of the testing and the opinions of the users, a User Survey form was developed by TACTEC, Boeing and the U.S. Army Soldier Systems Command. The surveys were filled out at the time of training, and are very comprehensive and detailed. Unfortunately, the surveys were completed by only four individuals, but the resulting data was compiled and is presented in Appendix A, and provides an average score for each of the attributes which were considered.

3.4.4 Lessons Learned. While much of the knowledge and research of this program are captured throughout the body of this report, a number of issues have occurred frequently enough that they should be considered the major lessons learned of the program. These issues are reiterated and explained further in the following paragraphs, and should be considered carefully on further development or projects involving human mounted computer systems. Additionally, Appendix B entitled "Recommended SOCM System Improvements", is provided as a guideline for future development and is based on the lessons learned of the program.

3.4.4.1 Display Systems. The single most commented and debated issue on the program was that of the display system. While this was not a display development program, the overall impression and usefulness of the system did heavily depend on which of the Commercial-Off-The-Shelf (COTS) display systems would be used. Unfortunately, no display available was the ideal solution for the application. All COTS displays suffered from being too fragile and intolerant to heat, cold, humidity and dust. All users expressed a desire for a full color display, which would be an enormous aid in viewing maps and diagrams. Further, for Special Operations use, a night vision integrated display was also strongly desired, to allow the operators to both see in the dark, and use the wearable system simultaneously. The author personally believes that the technology to build a near ideal display system is available, as was developed by DARPA during the '90's, but most display manufacturers are reluctant to develop the units, because of uncertain market demand, and the large up-front investment. Perhaps with the emergence of the Land Warrior, the Honeywell system will be the first truly acceptable HMD for the dismounted soldier, and others will begin to see a market emerge and will offer comparable products in the future.

3.4.4.2 Data Presentation. Even if an ideal display system was available, it is still a significant challenge to present the data acceptably on a 640 x 480 miniature display. A screen of information that looks great on a laptop or a desktop monitor may or may not be usable on a miniature display. Much work must go into carefully developing the data displays to be shown on these miniature displays. The author personally believes in retrospect that using Windows95 look and feel screen designs is not a good solution for a wearable system, and future designs should strive for a more embedded look.

3.4.4.3 Battery Performance. Boeing developed a custom battery for the system under the program based on Lithium Ion Polymer technology, but because of immaturity of the manufacturing process, the battery proved to be unreliable. Even with commercial Lithium rechargeable, system life was only in the 2-4 hour range, which proved to be inadequate in the field. A cable modification was made, to allow the users to use the standard BA-5590 primary Lithium battery, which is already used in military radios and other equipment. This provided over ten hours of system use in the field, and was viewed as a much better solution by the users. We learned that soldiers do not want a unique battery, and they also do not care if it is rechargeable. Soldiers want long system run time and a standard battery, making the system much easier to support in the field.

3.4.4.4 Cable Integration. One of the most complex issues of wearable system integration is the routing of cables in the vest and on the body. The difficulties are multiplied, as radios, GPS, WLAN and other peripherals are added. The need to support multiple configurations makes matters even worse. This results in a spider web of cables that must be routed through the vest, and winds up being heavy, unsightly and difficult to put on. One possible solution is to make the cables fully integrated with the vest, and non-removable. This would allow only the components to be removed, whereas the cables and connectors would be permanently in place, and permanently out of the way. This of course would sacrifice versatility and would be much more expensive to produce, but would result in a more robust and reliable vest design.

3.4.4.5 Communications. A number of lessons were learned about military communications with wearable computers. First, commercial Wireless LAN technology lacks the range and security for Special Operations use, although it does provide an adequate data transfer rate. Second, generating software to communicate over military radios can be very time consuming, complicated and expensive, and the end result will still be dependent on the capability of the radio itself. Data transfer rates using the MXF-610 radio were very slow (on the order of a 100's of bps) and the radios were very unreliable. Better results would be expected with the PRC-117, such as longer range and data rates on the order of 16Kbps. To work out any good communications scheme would require a significant effort, and early on laboratory work with the desired radios to verify the functionality.

3.4.4.6 Loading of Mission Information. A great degree of difficulty was experienced in getting the mission information loaded onto the SOCM computer prior to the deployment of the operators. This occurred in spite of the fact that Boeing had developed a Mission Setup utility for a laptop computer that was to expedite the process. The problem was that mission information comes from many sources, and arrives in many formats. An attempt was made early-on to determine the data formats of the mission information so that the mission setup utility could read it directly. Unfortunately, many of the formats could not be established, and some of those that could had either changed or were not strictly followed when the Operational Experiment occurred. This resulted in much of the mission information being typed in by hand, which is very undesirable and would never work in a real scenario. For future development, it is very important that a mission planning tool be developed that would provide the proper compatibility with the SOCM wearable computer, and could be used do both mission planning and preparation of the wearable system mission data.

4.0 Summary

The Special Operations Combat Management System Program was an aggressive, fast paced research and development project which used advanced microelectronics packaging technology to design, build and test a state of the art, high end Pentium computer. The computer was packaged into a small but rugged body worn configuration, and was integrated with other items to become a complete wearable soldier information system suitable for use by soldiers of the Air Force Special Operations Command. The system was integrated with military radios, commercial Wireless LAN technology, GPS and a Mission Software package to provide the soldier with advanced computer assisted information management, communications and navigation capabilities. The prototype SOCM wearable computer system was completed in less than seven months from contract Authorization-to-Proceed, and four deliverable systems were completed in less than one year. The resulting product, the SOCM wearable computer, was successfully tested in Operational Experiments with the 24th Special Tactics Squadron of the Air Force Special Operations Command, and has shown that the use of wearable computers can be a viable approach for information management in the military and Special Operations community.

4.1 Conclusion

Although some problems with the system were encountered, as would be expected with any prototype hardware being used in a field scenario, the user feedback and user evaluation surveys indicated that the systems, technology and the overall concept showed a great deal of potential for future application to Special Operations. A number of lessons were learned over the course of the program about aspects of the SOCM System design, including the things that worked well, as well as things which needed improvement or further development. For wearable computers to become fully accepted by the military and Special Operations community, further advances in size, weight, battery performance and most importantly, display systems are needed. Additionally, methods for user input must be tailored to the task, and made to work in a more streamlined or efficient manner.

While the SOCM program explored the use of wearable systems for only one specific application, it is felt that this program has only scratched the surface in exploring the multitude of uses for these systems and the benefits. Because these systems are substantial in size and weight, it is felt that in their present form, they will never be carried by every soldier, nor should they be; rather they are much better suited to provide focused solutions to very specific military uses, such as Digital Call For Fire, Surveying, Imagery Transmission etc. While the computer developed on this program is an open architecture generic system, it is felt that specific custom software and in some cases custom peripherals will be needed for each usage to provide the soldier with an optimal solution for his particular problem. Nevertheless, the SOCM program has provided the military with an advanced wearable soldier information system, much more advanced than any other system available, and a wealth of knowledge and research results which are applicable to present and future wearable systems, in a technology area that is destined to become a mainstay in the military forces of tomorrow.

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-99/035 in a series of reports approved for publication.

Appendix A: SOCM User Evaluation Survey Results

A.1 SOCM User Surveys

This Appendix contains the compiled results of the SOCM Field Evaluation User Surveys. The Surveys were completed in October and November 1998 following the TACTEC provided training and the Operational Field Experiment.

A.2 Survey Organization

The Surveys are broken into six individual surveys or "blocks" with overlapping questions. The blocks cover functionally related issues or areas of operation of the SOCM Systems, and are defined as follows:

- Block 1: System Integration and Fit
- Block 2: Displays and User Interfaces
- Block 3: Ease of Use
- Block 4: Communications and Navigation Functions
- Block 5: Mission Software Functionality and Utility
- Block 6: System Usability for Special Operations Forces

A.3 Survey Scoring

The survey questions were provided as statements, and were given a numerical score in the range of -3 to +3 by the survey participants. In the survey scoring, a -3 is the most negative response, zero is a neutral response, and a +3 is the most positive response. The scores were averaged, and the average is provided numerically and graphically next to the survey question. In addition, at the end of each survey, some open-ended questions appear, as well as a place for comments and recommendations. All responses received for these questions are included in this Appendix.

SOCM Field Evaluation User Survey
Block 1: System Integration and Fit

Survey Question	Avg. Score	Graphical Representation						
		-3	-2	-1	0	1	2	3
1. Ease of Identifying Components	2.75							
2. Integration of components	2.00							
3. Integration of Computer (CPU)	2.25							
4. Integration of Keyboard	2.00							
5. Integration of Radio Interface Box	1.50							
6. Integration of GPS	2.00							
7. Integration of Radios	1.00							
8. Integration of Cables/connectors	1.00							
9. Integration of Vest System	2.00							
10. Integration of Batteries	1.75							
11. Integration of Head Mounted Display	1.75							
12. Integration of Hand Held Display	1.33							
13. Integration of Mouse	2.00							
14. Instructions for installing	2.00							
15. Fit of components in pouch	2.75							
16. Pouch placement comfortable	2.00							
17. Ease of use	2.00							
18. System organization and arrangement	2.00							
19. Reliability of operation	1.50							
20. Cable routing instructions	1.75							
21. Ease of routing cables	1.00							
22. Comfort of movement with cables	2.00							
23. Instruction for fit	2.00							
24. Ease of adjustment for fit	2.25							
25. Ease of putting on	1.75							
26. Feel of balance	2.25							
27. Body flexibility-movement	2.33							

28. Comments/Recommendations:

- Place connectors at each end of all cables and make cables an integral part of the vest.
- All information was easy to understand.
- Keyboard cable might be better if run over shoulder and down arm.

SOCM Field Evaluation User Survey
Block 2: Displays and User Interfaces

Survey Question	Avg. Score	Graphical Representation						
		-3	-2	-1	0	1	2	3
1. Instruction for System Boot-up	2.50							
2. How did Power-On sequence work	1.75							
3. Visual Display clear and distinct	1.25							
4. Visual Display easy to use	1.75							
5. Software Instruction easy to follow	1.50							
6. Program easy to use	1.25							
7. Input Device worked well	1.75							
8. Navigation Methods worked well	2.00							
9. Icons / Symbols easy to understand	1.25							
10. Text easy to read	1.50							
11. Graphics easy to read	1.25							
12. Voice Commands easy to use	-0.50							
13. System power down instructions	1.50							
14. Power Down sequence worked well	1.00							
15. Actions with Mouse worked well	1.50							
16. Usefulness of Head-Mounted Display	2.25							
17. Usefulness of Hand-held Display	2.00							
18. System Organization /Arrangement	1.50							

19. How long did you use the Head-Mounted Display?

- Average of 14 hours per person.

20. How long did you use the Hand-Held Display?

- Average of 3.6 hours per person.

21. What do you Most Like about the Head-Mounted Display?

- Hands off use.
- Ability to move display from side to side to rest eyes.
- Frees up hands.
- Hands free.

22. What do you Least Like about the Head-Mounted Display?

- Incompatibility with NVG equipment.
- Protrudes too far from face.
- Fonts are small. I made them larger but still difficult to read because display is small.
- Hard to focus, Hard to keep focused.
- Difficult to use with Keyboard.
- Cannot be used with other head mounted Night vision devices.
- Too big and cumbersome.
- Not rugged enough.

23. What do you MOST LIKE about the Hand-Held Display?

- *Don't like it.*
- *More comfortable than the head-mounted.*
- *Easy to focus in on.*
- *Get to view boot-up process.*
- *Mouse and cursor keys buttons are integrated.*
- *Can put away when not using.*

24. What do you LEAST LIKE about the Hand-Held Display?

- *Hard to use mouse.*
- *Cumbersome.*
- *Another loose component to snag.*
- *Have to hold it up to your eye.*
- *Uses up one hand to see.*
- *It takes one hand to view, sometimes two hands if using mouse.*
- *Difficult to see in bright sunlight.*

25. Comments/Suggestions:

- *Putting all on disk.*
- *Color display on both. Also need to make head mounted display with side mounts for helmet.*

SOCM Field Evaluation User Survey
Block 3: Ease of Use

Survey Question	Avg. Score	Graphical Representation							
		-3	-2	-1	0	1	2	3	
1. Put on equipment quickly & easily	2.33								
2. Boot up system quickly & easily	2.75								
3. Access software quickly & easily	2.50								
4. Navigate programs quickly & easily	2.25								
5. Instruction easy to follow	2.25								
6. Perform tasks using voice commands	-1.00								

7. Comments / Recommendations:

- *System is relatively easy to understand and instructions seem to be easy to follow.*

SOCM Field Evaluation User Survey
Block 4: Communications and Navigation Functions

Survey Question	Avg. Score	Graphical Representation							
		-3	-2	-1	0	1	2	3	
1. Instructions for SP-TCIM set-up	2.25								
2. SP-TCIM loaded properly	2.50								
3. Instruction for WLAN set-up	2.00								
4. Frequencies loaded properly	1.25								
5. Radio communicated properly	-0.75								
6. Instructions for GPS set-up	2.25								
7. Program for GPS loaded properly	2.25								
8. Obtained accurate locations	3.00								
9. GPS easy to use	1.25								
10. Instructions for radio transfer set-up	0.33								
11. Cables easy to connect	2.00								
12. CPU & RIB worked	1.50								
13. Instructions for data transfer	1.33								
14. Data transfer by radio	-0.75								
15. Data transfer by WLAN	2.00								
16. Voice commands for data transfer	-0.33								
17. Receiving data by radio	-0.75								
18. Receiving data by WLAN	2.33								
19. Locating positions on map with GPS	3.00								
20. Verifying movements on map with GPS	3.00								

21. Comments/Recommendations:

- WLAN worked very well consistently. Requires greater range. Generated a lot of interest.
- GPS was also very accurate and reliable. Again, users like this capability very much.

SOCM Field Evaluation User Survey
Block 5: Mission Software Functionality

Survey Question	Avg. Score	Graphical Representation						
		-3	-2	-1	0	1	2	3
1. Mission Planning instructions	1.50					██████████		
2. Easy to use Primary Menu	1.75					██████████		
3. Easy to use Database Menu	0.75				████			
4. Easy to use Air Traffic Control Support	1.00				██████			
5. Air Traffic Control Support worked well	1.00				██████			
6. Wearable System a benefit to ATC	1.25					██████		
7. Easy to use Asset Management	1.00				██████			
8. Asset Management Support worked well	1.25					██████		
9. Wearable system a benefit to Asset Management	1.75					██████████		
10. Easy to use Communications Support	0.33				██			
11. Communications Support worked well	0.33				██			
12. Wearable System a benefit to Communications Support	1.33					██████		
13. Easy to use Map Support	1.75					██████████		
14. Map Support worked well	2.25					██████████		
15. Wearable System a benefit to Map Support	2.25					██████████		
16. Easy to use Weather Support	1.00				██████			
17. Weather Support worked well	1.00				██████			
18. Wearable System a benefit to Weather Support	0.66				███			
19. Easy to use Call-For-Fire Support	1.25					██████		
20. Call-For-Fire Support worked well	0.33				██			
21. Wearable System a benefit to Call-For-Fire Support	1.00				██████			
22. Easy to File Transfer Support	0.75				████			
23. File Transfer Support worked well	0.75				████			
24. Wearable system a benefit to File Transfer	0.75				████			
25. Easy to use Mission Graphics Viewer	1.75					██████████		
26. Mission Graphics Viewer worked well	2.00					██████████		
27. Wearable a benefit to Mission Graphics Viewer	2.00					██████████		

28. Comments/Recommendations:

- *Definite problem in file transfer using radios. Unknown if it is due to misinterpretation of instructions or hardware conflict. Needs to be looked at strongly.*
- *Air Traffic Control Support is useful as long as it is faster than current methods of monitoring/controlling ATC information. Evaluation showed no advantage at current configuration.*

SOCM Field Evaluation User Survey
Block 6: System Usability for Special Operations

Survey Question	Avg. Score	Graphical Representation						
		-3	-2	-1	0	1	2	3
1. Ease of putting on Vest System	2.25							
2. Quality of fit	2.50							
3. Integrates with other Tactical Equipment	-0.25							
4. Weight Distribution/Balance	1.75							
5. Stability while Moving	1.75							
6. Freedom of Arm Movement	2.00							
7. Freedom of Head Movement	2.25							
8. Ability to Bend Body	1.66							
9. Ability to Crawl while Wearing	0.66							
10. Ability to Run when Necessary	1.25							
11. Maintain Noise Discipline	1.75							
12. Maintain Light Discipline	1.00							
13. Head Display Readable in Daylight	1.50							
14. Head Display Readable in Darkness	2.75							
15. Ability to Head while Wearing Display	2.50							
16. Ability to Speak when Wearing Display	2.50							
17. Hand Display Readable in Daylight	1.50							
18. Hand Display Readable in Darkness	2.75							
19. Keyboard Use in Daylight	3.00							
20. Keyboard Use in Darkness	3.00							
21. Mouse Use in Daylight	3.00							
22. Mouse Use in Darkness	2.75							
23. GPS Use in Daylight	3.00							
24. GPS Use in Darkness	2.75							
25. MXF-610 Radio use in Daylight	1.66							
26. MXF-610 Radio use in Darkness	1.00							
27. Radio Interface use in Daylight	1.00							
28. Radio Interface use in Darkness	3.00							
29. Battery Changing in Daylight	1.50							
30. Battery Changing in Darkness	0.00							
31. System Operation in Wet Weather	0.00							
32. System Operation in Cold Weather	2.33							
33. System Operation in Hot Weather	2.00							
34. System Operation in Dusty Conditions	0.00							
35. Voice Operation in Noisy Environment	0.33							

36. Overall, How Acceptable is System	1.00								
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37. What improvements would you make to the vest or components?
- Consider integration of cabling (See block one questionnaire comments).

38. Comments/Recommendations:
- None

Survey Question	Avg. Score	Graphical Representation							
		-3	-2	-1	0	1	2	3	
Maintenance In Garrison:									
39. Ease of Cleaning Vest	2.33								
40. Ease of Cleaning Components	2.33								
41. Ease of Repairing Vest	1.66								
42. Ease of Repairing Components	1.66								
43. Ease of Storing Vest	2.66								
44. Ease of Storing Components	2.33								
Maintenance in the Field:									
45. Ease of Cleaning Vest	2.00								
46. Ease of Cleaning Components	1.00								
47. Ease of Repairing Vest	-1.50								
48. Ease of Repairing Components	-0.50								
49. Ease of Storing Vest	2.50								
50. Ease of Storing Components	1.50								
Durability/Safety:									
51. Durability and Strength of System	1.00								
52. Safe to Operate in Wet Weather	1.00								
53. Safe to Operate in Cold Weather	2.00								
54. Safe to Operate in Hot Weather	1.75								
55. Safe to Operate in Dusty Conditions	1.00								
Troubleshooting:									
56. Vest Troubleshooting Instructions	1.00								
57. Overall System TS Instructions	-1.00								

58. Recommendations for Improving Maintenance:
- Design a field cleaning/maintenance kit including instructions for use.
- There currently aren't any provisions for repairing vests/fabric components in the field. Consider including spares with systems.

Survey Question	Avg. Score	Graphical Representation							
		-3	-2	-1	0	1	2	3	
Miscellaneous:									
59. Ease of Doffing in Emergency	1.00								
60. Ability to Zero if Compromised:	-1.33								
61. Battery Life	-1.50								
62. Ease of Changing Batteries	0.75								
63. Initialization after Battery Charge	0.00								

64. Comments/Recommendations:

- Hot swapping of batteries is desired.
- Need more reliable indicator of battery condition, i.e., use Windows battery monitor to give heads up indication of status.
- Use the BA-5590 battery!

Appendix B: SOCM System Improvement Recommendations -

B.1 Introduction.

This paper addresses the issues and suggestions that were identified during the SOCM Operational Experiment conducted by TACTEC and the 24th Special Tactics Squadron of USAFSOC during October 1998. The major issues are discussed, and a Boeing recommendation is presented. In many cases, a consensus among the users does not exist, and further exploration of the problem would be required before a solution can be recommended.

B.2 Hardware Issues

B.2.1 CPU. In general, the CPU functioned well in the Operational Experiment. Hard drive size was an issue, as the small size of the PCMCIA drive prevented the use of power management functions. PCMCIA drives are also power hungry, compared to the newer IDE drives, which further degraded the battery performance. The users suggested that in the future, flash memory should be used to further increase the shock tolerance of the system, although no problems were encountered in this area. Guarded switches were requested to prevent inadvertent switch depression.

Recommendations: On current production systems, the 1.4GB IDE drives should be used as the standard system hard drive. For future generations, a more current IDE drive should be used, and the use of solid state memory (flash) should be strongly explored. The major problem with flash at this point is the small size (available only up to 300MB) and high cost. Additionally, guarded switches or recessed snap dome switches should be used on future versions of the CPU.

B.2.2 Keyboard: The keyboard also functioned well during the field experiments, but some minor changes were suggested to improve the functionality. First, it was suggested to change the CAP key to a SHIFT key. Also, to improve versatility, it was suggested to modify the cable exit point to allow the keyboard to be worn on the right or left arm, and also even to consider mounting the keyboard on the face of the CPU.

Recommendations: Keyboard mounting should be further explored to determine the most versatile mounting methodology. Mounting of the keyboard onto the CPU, either magnetically or with hinges should be considered as an additional possibility. The shift key can be implemented with minor design changes to the Keyboard key labeling and the firmware.

B.2.3 Mouse. Neither the hand held mouse nor the mouse integrated into the hand held display were found to be completely satisfactory in the experiments. The display mouse was difficult to use due to the positioning of the thumb control and the buttons, and the hand held mouse, although somewhat easier, was still awkward to use, and did not fit into the hand properly.

Recommendations: In future designs, a human factors consultation is recommended to establish what if any changes could be done to improve the usefulness of each mouse. By molding the mouse into a hand-fitting shape and repositioning the buttons, it is possible to achieve a much more ergonomic design, that is easier to operate and hold. Because both mice are built from molded plastic, design changes will be costly, so a trial and error approach is not recommended. Rather, some non-functional mouse prototypes could be constructed to help to evaluate the mouse design options.

B.2.4 Batteries. Boeing developed a custom battery for the system under the program based on Lithium Ion Polymer technology, but because of immaturity of the manufacturing process, the battery proved to be unreliable. Even with commercial Lithium rechargeable, system life was only in the 2-4 hour range, which proved to be inadequate in the field. A cable modification was made, to allow the users to use the standard BA-5590 primary Lithium battery, which is already used in military radios and other equipment. This provided over ten hours of system use in the field, and was viewed as a much better solution by the users. We learned that soldiers do not want a unique battery, and they also do not care if it is rechargeable. Soldiers want long system run time and a standard battery, making the system much easier to support in the field. Also, hot swapping is desired.

Recommendations: To satisfying the requirement of long runtime and field supportability, it is recommended that future systems be delivered with the capability to operate with the BA-5590 primary lithium battery. To accomplish this, a battery pouch modification would be needed as well as a cable assembly to connect to the battery, which uses a unique connector. For future development new battery technologies with higher capacity and smaller size should continue to be explored.

B.2.5 Displays: The single most commented and debated issue on the program was that of the display system. While this was not a display development program, the overall impression and usefulness of the system did heavily depend on which of the Commercial-Off-The-Shelf (COTS) display systems would be used. Unfortunately, no display available was the ideal solution for the application. All COTS displays suffered from being too fragile and intolerant to heat, cold, humidity and dust. All users expressed a desire for a full color display, which would be an enormous aid in viewing maps and diagrams. Further, for Special Operations use, a night vision integrated display was also strongly desired, to allow the operators to both see in the dark, and use the wearable system simultaneously.

Recommendations: The author personally believes that the technology to build a near ideal display system is available, as was developed by DARPA during the '90's, but most display manufacturers are reluctant to develop the units, because of uncertain market demand, and the large up-front investment. Perhaps with the emergence of the Land Warrior, the Honeywell system will be the first truly acceptable HMD for the dismounted soldier, and others will begin to see a market emerge and will offer comparable products in the future. The Honeywell system should be investigated when it is available for

purchase, and other systems built by Seattle Sight Systems and Kaiser Electro Optical should be monitored for improvements as well.

B.2.6 Cable Integration. One of the most complex issues of wearable system integration is the routing of cables in the vest and on the body. The difficulties are multiplied, as radios, GPS, WLAN and other peripherals are added. The need to support multiple configurations makes matters even worse. This results in a spider web of cables that must be routed through the vest, and winds up being heavy, unsightly and difficult to put on.

Recommendations: One possible solution is to make the cables fully integrated with the vest, and non-removable. This would allow only the components to be removed, whereas the cables and connectors would remain in place and out of the way. This of course would sacrifice versatility and would be much more expensive to produce, but would result in a more robust and reliable vest design.

B.2.7 GPS: Most users complained that the SOLGR GPS was too complicated to use, and would prefer to stay with the PLGR that they are already using.

Recommendations: The PLGR GPS can be used with the existing software on the SOCM system. A modification to the pouch is needed, as well as the GPS cable on the system, but otherwise, this change is recommended.

B.2.8 Radio. Data transfer rates using the MXF-610 radio were very slow (on the order of a 100's of bps) and the radios were very unreliable. Better results would be expected with the PRC-117, such as longer range and data rates on the order of 16Kbps, but due to time constraints and limited radio resources, this concept was not fully tested. To work out any good communications scheme would require a significant effort, and early on laboratory work with the desired radios to verify the functionality. Generating software to communicate over military radios can be very time consuming, complicated and expensive, and the end result will still be dependent on the capability of the radio itself.

Recommendations: A more robust radio system is needed for battlefield networking of wearable computer systems. The MCS / FBCB2 system should be carefully monitored, as well as emerging radio projects such as the MSSSI Ultra wide band system being developed for OST. For near term solutions, the PRC-117 radio capability should be further explored and developed, as well as schemes to compress data and images to make the current available bandwidth an acceptable solution until the emergence of the next generation systems.

B.2.9 Wireless LAN. A number of lessons were learned about military communications with wearable computers. First, commercial Wireless LAN technology lacks the range and security for Special Operations use, although it does provide an adequate data transfer rate. Second, a more streamlined method must be developed for sending and receiving data files, and getting them into the users database. The wireless LANs work quite well in open line of sight applications, provided that the users remain within the

range of the system, but for battlefield operations, a longer range system is needed. Issues were also raised regarding the fragility of the LAN antenna.

Recommendations: One possibility is that a secure version of the LAN could be implemented, with the assistance of the LAN developer. The further exploration of access points and long range antennas should continue, and have the potential to solve some of the range issues. However, a fully developed secure battlefield Local Area Network system is still needed, and hopefully will emerge from the Battlefield Tactical Internet or other projects.

B.2.10 Radio Interface Box (RIB). Users were generally not happy with the radio interface box. The complaints were that it was bulky and uncomfortable, hard to see in the dark, difficult to use the switches, and the switches were not guarded, so could be inadvertently changed. Because the RIB was designed to support two military radios using standard audio connectors, size was a significant problem. For each radio, it was necessary to supply a data-in port, audio in, and radio out, resulting in a total of 6 connectors, plus one small one for power.

Recommendations: On this program, the RIB was designed to be worn on the body. For future designs, it should be taken off the body and placed on the radio, as well as made to operate only one radio. This would significantly reduce the size, and improve its acceptability to the users. Other design modifications could implement a better switching scheme, including the possibly of software switching. Another possibility is to completely eliminate the RIB, and utilize the radio in data only mode, which would result in removing the need to accomplish voice/data switching in the transmission path between the computer and the radio.

Any approach chosen will likely result in a complete redesign of the radio interface box, and should include a human factors analysis of the functionality, as well as the positioning of the switches.

B.3 Software

B.3.1 Loading of Mission Information. A great degree of difficulty was experienced in getting the mission information loaded onto the SOCM computer prior to the deployment of the operators. This occurred in spite of the fact that Boeing had developed a Mission Setup utility for a laptop computer to expedite the process. The problem was that mission information comes from many sources, and arrives in many formats. An attempt was made early on to determine the data formats of the mission information so that the mission setup utility could read it directly. Unfortunately, many of the formats could not be established, and some of those that could had either changed or were not strictly followed when the Operational Experiment occurred. This resulted in much of the mission information being typed in by hand, which is very undesirable and would never work in a real scenario.

Recommendations: See **Mission Data Formats**, below.

B.3.2 Mission Data Formats. A number of minor problems were encountered with the format of the presentation of the mission data, such as which fields should be editable, window sizing, difficulty in editing data in the field, and the need for time stamps to appear in the window.

Recommendations: Many of these individual requests are straightforward to implement in the software. However, the entire methodology for collecting, loading and displaying the data should be reconsidered. Many of the formats have changed, or do not satisfy what the user now seems to need, although it did seem to at the time the software was being developed. In many cases, the user now seems to be requesting the capability to simply view an Excel spreadsheet, whereas before, the SOCM software actually read the mission data into a database, and provided functions for selectively displaying, sorting, editing, and other special features. Human factors expertise should be heavily utilized in any future attempt to revamp the mission data display features in order to insure that not only will the data be displayed in a useful form, but that it will be easier to collect and load from its source of origination.

B.3.3 Operating System. During the experiments, it was suggested that changing the operating system from Windows95 to Windows NT could perhaps have improved networking functions.

Recommendations: This is a possibility; however at the time the software was developed, available versions of Windows NT did not support the PCMCIA card slots provided on the SOCM computer, and therefore was not considered. Windows NT should be reevaluated and tested in this respect prior to making a commitment. Other operating systems should also be considered, keeping in mind issues such as compatibility of applications, imbedded power management features and networking features. It is possible that another operating system could be selected which would improve the networking capabilities while providing the needed functionality and compatibility.