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USAWC STRATEGIC RESEARCH PROJECT

DIGITIZATION OF THE BATTLEFIELD

by

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ABSTRACT

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The introduction of information based weapon systems capable of providing combat vehicle crews with not only the effective firepower of larger organizations but also the knowledge base to coordinate and employ both on-board and external sensors and weapons will change the current tactics, techniques and procedures of the U.S. Army. Various issues associated with the "digitization of the battlefield" are discussed including protocols, communications requirements, organizational changes, sensor fusion options, and the impact of technology on 21st century warfare.

> **One should be skeptical of any military strategist who claims certainty about the future of warfare, especially those who assert that technology changes the fundamental nature of war.[1]**
>
> General Gordon R. Sullivan

I.
THE NEW WORLD

The purpose of this paper is to demystify the term "digitization of the battlefield," put the information processing technology of the microchip into perspective, assess the current impact of digitizing weapon systems, and discuss digitization's potential to change the American way of war in the 21st Century.

The unprecedented success of the American armed forces in the Gulf War has given rise to many declarations of the birth of a new form of warfare based on the technology of the microchip and the processing of digitally encoded information. As LTG(ret.) Frederick Brown has recently observed, "The technological arbiter of land power success has moved from the internal *combustion* engine and atom to the microchip."[2]

The internal combustion engine and the radio coupled with *Blitzkrieg* tactics introduced a speed of warfare that exceeded the capacity of outdated militaries to respond effectively. The overwhelming success of the Germans in Poland and France was heralded as a revolution in warfare. The microchip coupled with information based tactics is seen as the next quantum leap forward in gaining a decisive edge in warfare.

The utilization of the microchip, by both men and machines, to process information is seen as the key element for achieving future victory. By facilitating our ability to turn within the decision loop of the enemy, we will be able to outmaneuver him physically and mentally.[3] This can occur at the tactical, operational or strategic levels of war by obtaining and acting on information faster than our opponent. It is this generation, movement, processing, displaying, and utilization of information digitally by both men and machines that gives rise to the term "digitization of the battlefield."

Before discussing digitization's impact, a brief description of what is meant by the term "digital" is necessary. Digitization is the encoding of any information into a discrete or discontinuous signal by partitioning the signal and assigning it a numerical binary code (one/zero) value. These codes are less sensitive to noise, interference from other frequencies, signal distortion and fading, and have greater transmission efficiency than continuously variable (analog) signals. Because these signals are in a numerical code they can be processed by computers using mathematical algorithms to manipulate the information for many purposes. Conversion of the digital signal into an analog signal is done by use of a modulator - demodulator (modem) device.[4] This digital technology and the analog-to-digital / digital-to-analog conversions are the physical bases that permit the transmission and processing of vast amounts of data by computers and is the enabling technology of the "information age."

II.
THE INFORMATION AGE

The description of the information age and information based warfare, called Third Wave War, was discussed by futurists, Alvin and Heidi Toffler. Their underlying theory is that warfare has gone through three major revolutions based on societal structure. First Wave War was based on cyclical patterns of war driven by agricultural needs. Second Wave War resulted from the massification of society and armies as a result of the Industrial Revolution. Third Wave War is now emerging as information based war.[5]

> "A military revolution, in the fullest sense, occurs only when a new civilization arises to challenge the old, when an entire society transforms itself, forcing its armed services to change at every level simultaneously - from technology and culture to organization, strategy, tactics, training, doctrine, and logistics. When this happens, the relationship of the military to the economy and society is transformed, and the military balance of power on earth is shattered."[6]

The transformation bringing about this latest revolution is the integration of information technology from the civil sector into the military structure of the United States. The physical manifestation of this revolution in the U.S. Army is often called "digitization of the battlefield." The physical devices of information technology are only an element, although an important one, in this revolution. The other element is the intellectual renaissance that is taking place to exploit the technology to support military operations.

This second element is embodied by the growing body of military thought and writings devoted to what was first termed the Military Technological Revolution (MTR) and then later expanded to the Revolution in Military Affairs (RMA). The MTR/RMA is a result of a combination of factors that began about twenty-five years ago with the introduction of smart weapons. It continues to gain influence over the technologies, organizations, and doctrinal thinking of the military as new ways are thought of to use and exploit information technology to train, organize, and fight. In their monograph, *Land Warfare in the 21st Century*, General Sullivan, the Army Chief of Staff, and LTC Dubik identify the MTR as one of three elements of change that will have the most profound effect on future warfare.[7] However, as the opening quotation in Section I. clearly warns, one must beware of the claim that technology alone will change the nature of war.

The "military-technical revolution" discussed by Sullivan and Dubik is defined by five dominant technological trends:

Trends

- Lethality and dispersion
- Volume and precision of fire
- Integrative technology
- Mass and effects
- Invisibility and detectability[8]

Others are using the term Revolution in Military Affairs to refer to many aspects of military forces besides technology including the combination of innovative technologies, doctrine, operational concepts, and military organization.[9]

Another term for the RMA, "Cyberwar," was recently coined by John Arquilla and David Ronfeldt of the Rand Corporation.

> "Cyberwar refers to conducting and, preparing to conduct, military operations according to information-related principles. It means disrupting, if not destroying, information and communication systems, broadly defined to include even military culture, on which an adversary relies in order to know itself: who it is, where it is, what it can do when, why it is fighting, which threats to counter first, and so forth. It means trying to know everything about an adversary while keeping the adversary from knowing much about oneself. It means

turning the "balance of information and knowledge" in one's favor, especially if the balance of forces is not. It means using knowledge so that less capital and labor may have to be expended."[10]

All of these thoughts contain the common thread that those who best use digitally processed information in the future will become the dominant military power in the world.

To re-engineer the American Army to lead the world in information warfare, General Sullivan has promulgated a strategic vision to focus the change process. It is:

<u>The Army's Strategic Vision</u>

- A total force trained and ready to fight
- Serving the nation at home and abroad
- A strategic force capable of decisive victory[11]

The plan for achieving this vision in the Information Age is discussed in the next section.

III.
BRINGING THE ARMY INTO THE INFORMATION AGE

The Army cannot simply stop operating while it changes. It must remain operationally ready at all times to meet any contingency that may arise. Over a period of years, six imperatives were identified that must be continuously kept in balance to maintain a trained and ready force even while change is taking place within that force. The imperatives, within a fiscally-constrained Army program, to insure that the force remains trained and ready while the Army transitions into the Information Age are:

Imperatives

- Quality people
- Training
- Force mix
- Doctrine
- Leader development
- Modernization[12]

To accomplish modernization while keeping the Army trained and ready an updated modernization vision was published in January 1993. The modernization vision, phrased as "Land Force Dominance,"[13] requires that we retain and further advance the technological edge that the United States has attained with its current generation of weapon systems.

Modernization of the force will be accomplished by inserting information technologies into existing systems, where practical, and developing new information based weapon systems. To achieve land force dominance, specific objective capabilities were established in the modernization plan. The five capabilities to achieve the vision are:

Capabilities

- Project and sustain the force
- Protect the force
- Win the battlefield information war
- Conduct precision strikes throughout the battlefield
- Dominate the maneuver battle[14]

The modernization effort is also impacted by the development and procurement of capabilities that are not weapon system specific but bring objective capabilities to multiple systems. The term Horizontal Technology Integration (HTI) has been given to the application of common technologies across multiple systems to improve the war fighting capability of the force.[15] These common capabilities are called enabling strategies and are:

ENABLING STRATEGIES

- Own the Night
- Battlefield Combat Identification
- Battlefield Synchronization at Brigade and Below - Digitization*
- Battlefield Synchronization at Division and Echelons Above Division

* TRADOC uses Third Wave Battle command and Digitization synonymously

Digital information technology is the common element in each of the nine modernization capabilities or enabling strategies. The systems to achieve each of these capabilities will be microprocessor controlled and information driven. The requirements to do world-wide intransit asset tracking and accountability to project the force, through internetted databases for the synchronization of operations throughout the battlefield, require the application of advanced information processing capability as well as the integration of global communications capabilities into a seamless architecture.

The Tofflers postulated that information based technologies would cause the integration of the civil and military information infrastructures of a nation.[16] Prior to this latest modernization drive there were not only separate civil and military communications and information infrastructures but also separate infrastructures within the Army itself.

The Army had separate systems for its administrative and base operations organizations and its tactical field organizations. The concept of split base operations where units will be deployed directly from bases in the United States and are then supported logistically and operationally with assets that remain stateside is now forcing the information and communications integration of these assets.

The Army's Command, Control, Communications, Computer and Intelligence (C4I) community has developed an Enterprise Strategy to address the information needs of the Army as a generic whole and then augment the capabilities with commercial technologies validating the Tofflers' prediction. Through the Enterprise Strategy, the Army is attempting to integrate its non-tactical information structure to support its forward soldiers and their tactical systems.

The strategy consists of a vision based on ten principles and an implementation plan. The intent is to deliver the correct information whenever and wherever it is needed by the most efficient technology available in either the military or civil sector. The principles are:

Enterprise Strategy Principles

- Focus on the Warfighter
- Ensure Joint Interoperability
- Capitalize on Space - Based Assets
- Digitize the Battlefield
- Modernize Power Projection Platforms
- Optimize the Information Technology Environment
- Implement Multi - Level Security
- Ensure Spectrum Supremacy
- Acquire Integrated Systems Using Commercial Technology
- Exploit Modeling and Simulation[17]

There is a line of thought that digitizing the battlefield is only automating the command and control function for improving the speed and accuracy of information. This concept is only partially correct in that this is only a small, although critical, portion of the military technology and information technology revolutions. As can be seen above from the interrelationships of the various strategies, plans and visions digitization covers a much larger area.

The essence of digitizing the battlefield is captured in the Enterprise Strategy. It is defined as providing "the Warfighter an integrated digital information network that supports *warfighting systems* (emphasis added) and assures C2 decision-cycle superiority."[18] I will return to this point because it is essential that the reader understand that digitization of the battlefield is much more than just improving what was traditionally defined as moving and processing command and control (C2) information.

The succeeding sections cover the various digital information technologies, the major issues associated with the implementation of the technologies, their impacts on communications systems, some possible short and long term solutions and an example of how the Army of the 21st century may be organized and equipped to fight.

IV.
THE TECHNOLOGY

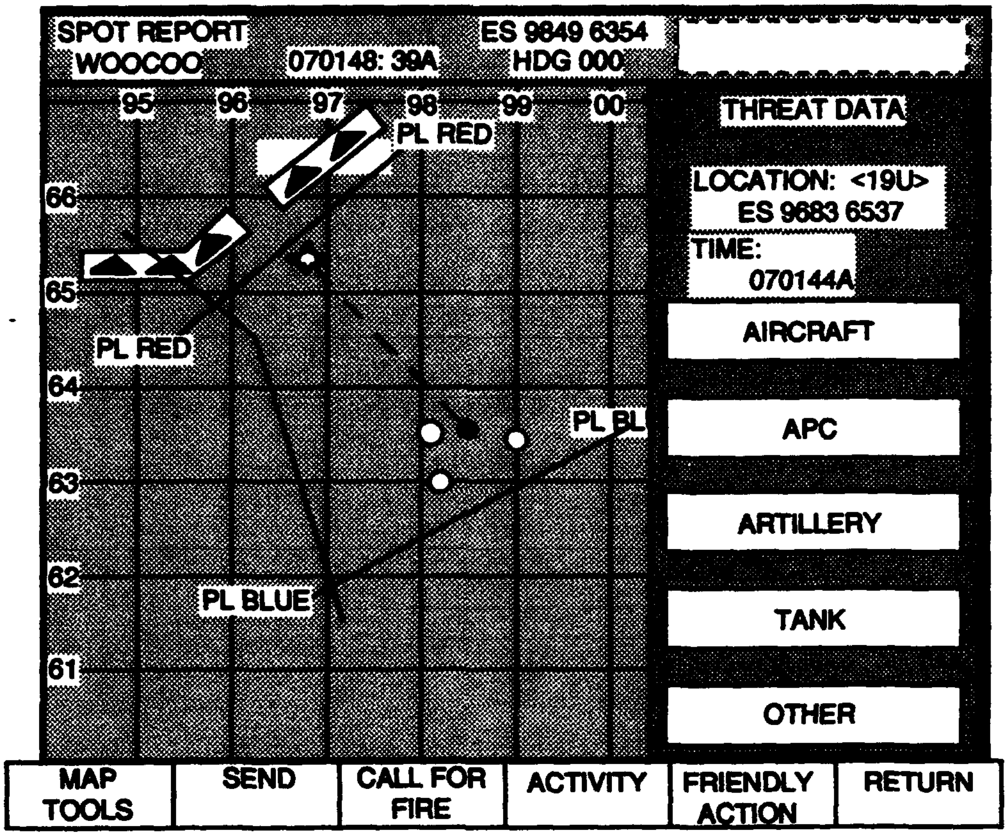
The installation of a microprocessor, databus, monochromatic flat panel display, and modem in the M1A2 tank opened the flood gates of the information revolution in the Army. This weapon system, for the first time, provides the tank crew in the close combat fight the ability to not only report information digitally but also receive, analyze and display information augmenting their perception or situational awareness of the battlefield. While doing this, the tank simultaneously provides the same information to the next level commander via his vehicle's radios and display. In addition to the command and control functions, the integrated vehicle electronics system (vetronics) digitizes all internal electronic information (except the thermal sight video) allowing the tank's operating data to be processed for use by both the crew, or by anyone to whom the data can be digitally transmitted.

Previously, all digital command and control systems such as the Maneuver Control System required manual entry of data at the lowest level of the database. This was a great weakness. The person entering the data was not a recipient of a database information product but merely required to enter data which did not help him in his fight. He could actually transmit the data quicker simply by using the radio.

The M1A2 tank is a computer that not only controls its internal operating functions but is also networked. The vehicle can "talk" digitally to other tanks and computers through its SINCGARS FM radio in a local area network. The tank, besides providing protection, mobility and lethal weapons for the crew, is now their personal digital assistant.

The M1A2 is the first front line system that, by means of its software, is capable of automatically generating and sending the input data with minimal operator effort. The tank is also able to process and provide usable information to its crew using its internal information processing functions and by exchanging information with other tanks.

The system generates a distributed database of command and control information, utilizing the Inter-Vehicular Information System (IVIS) software resident in all tanks on the net. Each tank has the ability to automatically share its information with other vehicles and can be configured internally to process and display data in a format understandable to and configured by each individual tank crew. An example of an M1A2 tactical display is shown below:



The black dot represents the location of the tank in which you are riding and on whose IVIS screen you are looking. Its own location, as determined by its on-board, inertial, position navigation system (POSNAV), is displayed in the upper box on the display (ES 9849 6354). The three open circles are the other tanks in the platoon whose positions are digitally reported over the platoon radio net at a prescribed interval or whenever they move a specified distance.

In the above display, the tank gunner or commander has just used the laser range finder (dotted line) to determine the range to an enemy target which is represented by the flower-like icon. The location of the target is automatically calculated by the tank's computer and its precise location is displayed in the preformatted message box on the right (ES 9683 6537).

To format the information as either a spot report or call for a fire mission, the vehicle commander merely selects the necessary menu items with his finger controlled cursor and presses the send button on the display. The data, if sent as a spot report, will be automatically transmitted and displayed in each of the other tanks in the platoon. Both the platoon leader's and the platoon sergeant's vehicles, with radios on both the platoon and company radio nets, can retransmit the spot report on the company net by the vehicle commander pressing a single button once he has reviewed it. If selected, reports can be automatically retransmitted by the leader's vehicle to the next level of command.

The spot report is transmitted with an IVIS Net Radio Protocol (NRP). This is an adaptation of the STANAG 4202 protocol for use on combat vehicles. When the message is transmitted as a fire mission for entry into the artillery digital fire net, the IVIS system automatically transforms the message to a TACFIRE protocol and switches the SINCGARS radio to the TACFIRE net for the data exchange. In addition, it will automatically transmit a "Call for Fire" message advisory on the IVIS net to inform net members that a call for fire has been issued.

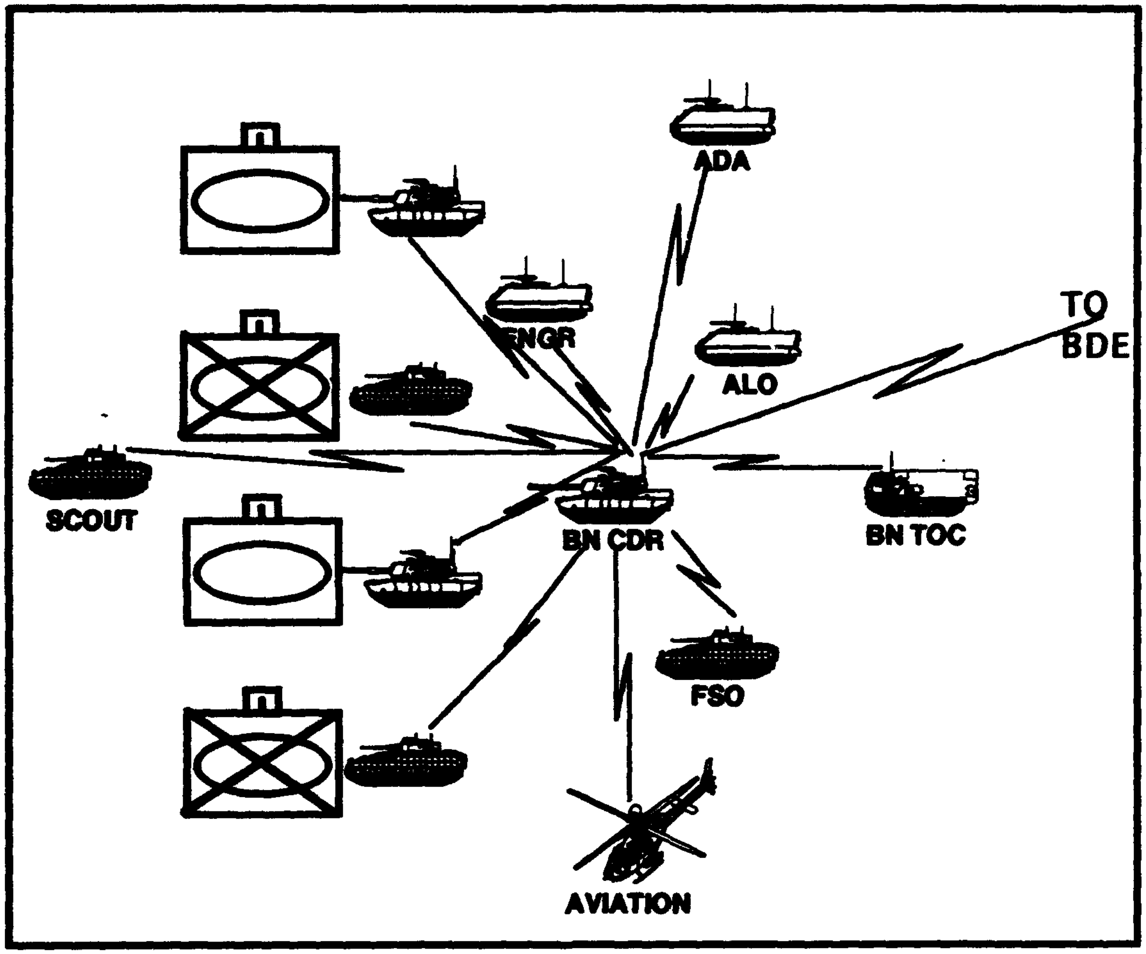
The IVIS equipped tank must not only communicate with other tanks but it also serves as the first level automated input device to the Army's command and control systems. The IVIS equipped M1A2 cannot currently communicate with the other elements and systems within a normal task force. It must do so if the first level of digital information flow is to be achieved at the tactical level.

As a node on the company or battalion net a tank must transmit data not only to the other company and battalion level tanks but also to many other recipients. The following is an illustration of the data inernetting required by a battalion commander's M1A2. It must communicate with:

• The battalion command post (TOC) which contains a terminal for either the Maneuver Control System or the new Army Command and Control System (ACCS)

• The Fire Support Officer's track with a TACFIRE/AFATDS input device

• The Air Liaison Officer's track with its voice and HF radios



DATA LINKAGE REQUIREMENTS FOR A BATTALION COMMANDER

• The supporting Engineers in M113's with FM voice only

• The Air Defense Platoon with its Forward Area Air Defense C2I (FAADC2) input device

• The mechanized infantry and scouts of the task force who will have M2A3 and M3A3 vehicles with digital capability, and eventually

• Individual infantrymen equipped with a helmet mounted heads-up display and a computer/radio subsystem similar to the technology demonstrator called the Soldier's Integrated Protective Ensemble (SIPE)

• Additionally digital communications will be required with helicopters including the OH-58D Kiowa, AH-64C/D Apache and RAH-66 Comanche as these systems evolve.

The requirements for digital communications links and data transfer described above are simply enhancements for command, control, and coordination communications. We currently accomplish these tasks by talking on FM voice radios and Mobile Subscriber Equipment telephones. Digital data linkages must be established over the same nets if no changes in doctrine, tactics, techniques or procedures are made other than to speed the flow of information. The improvements in the command and control function come from better sensing accuracy and speed by relying on the automatic routing and retransmittal of messages through the various levels of command. The recipients at the various headquarters can then manipulate and display this data using their computers.

What appears on the surface to be an easy problem is in fact quite difficult as each of the systems described has its own unique protocols and message formats. Unfortunately, the inflexible designs of many of these systems cannot be changed as they were not required to communicate with other digital data systems when they were designed. This is where the first in a series of major digitization issues appear.

I. Each of the digital systems now extant on the battlefield has its own Net Radio Protocols (NRP) and message formats and are therefore incompatible.

There are several possible solutions for this dilemma:

• Adopt a standard Net Radio Protocol and message text format for all systems and pay the one time price to modify all current systems to this standard.

• Develop a standard translator program that will allow a new system to use not only the new standard protocols but also communicate (transmit to and receive from) the older unique systems in their native protocols.

• Build gateway devices that require a physical linkage between an old style unique system and a new system somewhere at an interface location.

The last option can be immediately eliminated as it is equipment intensive and costly. It is also operationally unsound as single vulnerable linkage nodes are created that can be attacked thus destroying the inter-system information conduits.

The standard net radio protocol solution has a lot of appeal. The idea of getting everyone's digital device to speak the same language makes sense. However, what is the universal language that will satisfy every digital data system's information needs? "To date the Defense Information Systems Agency (DISA) has identified nearly 1,200 legacy mission-support applications and more than 20,000 legacy C2 and Intelligence applications."[19] Finding and validating the one protocol that allows the data satisfaction for a vast majority of these digital systems will be a formidable goal.

The Army is currently pursuing the concept of designating a single protocol. It is attempting to implement Interoperability Standards for Digital Message Device Subsystems (MIL-STD-188-220) and the Variable Format Message (VMF) as the target suite of common protocols for horizontal interoperability at brigade and below echelons.[20] This could possibly be a high risk solution since no system has yet to be fielded and verified with MIL-STD-188-220 messages and protocols.

The first system planned to implement the MIL-STD will be the new Advanced Field Artillery Tactical Data System (AFATDS). Furthermore this particular solution- or any other common protocol solution must be verified as meeting the operational needs of every digital data system if it is to be adopted.

Other much more ambitious protocols are already emerging. Asynchronous Transfer Mode (ATM) technology is already being looked at as the next generation common protocol in the commercial and military sectors. This protocol allows the transfer of voice, data and video over a single network to multiple addressees simultaneously. Under a program called the Secure Survivable Communications Network (SSCN) GTE Government Systems Division is developing the Secure Prioritized ATM Network (SPANet) node equipment. One segment of this program is a low-rate data interface card to get the data down to tactical users thus the ATM protocol will become a competitor to the MIL-STD-188-220 protocol on the lower level nets.[21]

The idea of translator programs has been implemented by the commercial computer industry as a solution the digital data incompatibility between such systems as the IBM based MS-DOS and the Apple Macintosh line of computers. A simple program called MacLinkPlus™ allows the immediate transfer and conversion of word processing, graphics, spreadsheets, and databases as well as direct hookups between these two incompatible machines and operating systems. The program contains over 1,000 translation combinations.[22]

Unisys Corporation is approaching the Defense Department's problem from a similar angle with a concept called "middleware". Middleware is proposed "as a class of software for a distributed processing system built of incompatible processors and applications... Middleware tools manage the various resources and perform the required data protocol translations for the legacy hardware, software and telecommunications links."[23]

To accomplish a first time field demonstration of multi-system digital interoperability at Ft. Knox during March 1993, the IVIS software of an M1A2 tank was modified so that it could translate and transmit using not only IVIS formats and protocols, but also the digital format of the TACFIRE system.[24] Although not the best solution to the protocol quandary this may be the most viable short term answer until a truly common protocol can be agreed upon.

IV.
COMMAND AND CONTROL
IN
THE INFORMATION AGE

A second digitization issue arises when the basic concept of command and control is addressed in light of this new technology.

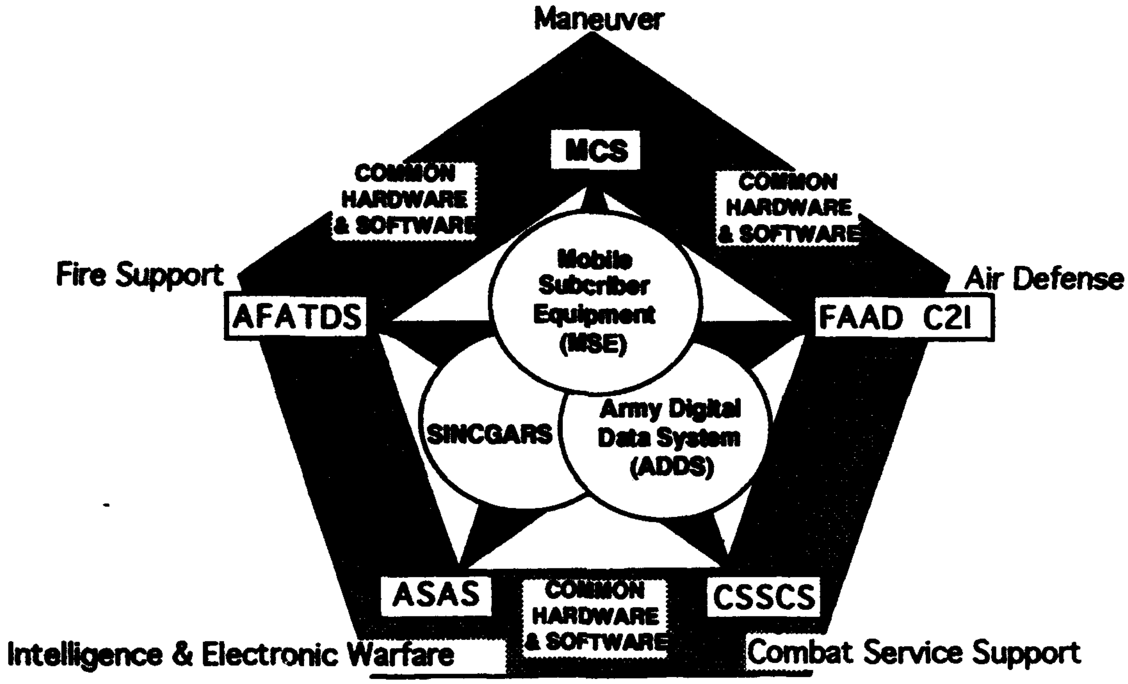
II. Automation of command and control functions is <u>not</u> digitization of the battlefield.

In the past the Army attempted to improve command and control merely by using computers to automate and speed up functions previously performed with voice message traffic, grease pencil overlays on maps and mimeographed plans and orders.

The architecture for this effort relied on the automation of the five battlefield functional areas (Maneuver, Fire Support, Air Defense, Intelligence and Electronic Warfare, and Combat Service Support) and the communications systems to link them in a distributed system. The three primary communications systems to support this architecture were:

- Mobile Subscriber Equipment (MSE) - providing voice and data common user communications at Corps and below.
- Single Channel Ground/Airborne Radio System (SINCGARS) - providing voice and some data capability for use by combat and combat support units at all levels.
- Army Data Distribution System (ADDS) - a family of data communication systems including:
  - Enhanced Position Location Reporting System (EPLRS) - a low capacity (4.8 Kbps) data communications system to carry tactical data

•• Joint Tactical Information Distribution System (JTIDS) nodes - a high capacity (238 Kbps) data system for transmitting air defense and other data between services



Army TacticalCommand and Control Architecture

This backbone communications structure is designed to be the data transport medium for the information in the Army's five tactical command and control systems.

Through the use of common hardware (computers) and a core common software structure, each Battlefield Functional Area Control System (BFACS) software package is designed to manage, coordinate, and process information internal to its functional area. The five functional areas and their respective control system software packages are:

- Maneuver - Maneuver Control System (MCS)
- Fire Support - Advanced Field Artillery Tactical Data System (AFATDS)
- Air Defense - Forward Area Air Defense Command and Control System (FAAD C2S)
- Intelligence/Electronic Warfare (IEW) - All Source Analysis System (ASAS), and
- Combat Service Support (CSS) - Combat Service Support Control System (CSSCS)

The UNIX based Common Software Program, within the Common Hardware/Software (CHS) Program, was to be the integrating common support and applications software that allowed the exchange of information horizontally and vertically among the five functional software packages. CHS was to provide the data transmission protocols, error correction algorithms and network management architectures for use on the three communications systems enumerated above.[25] Unfortunately, common standards have not been established and other systems such as IVIS were forced to develop their own solutions as interim fixes. (A separate discussion of the limitations and capabilities of the backbone communications systems is found in Section VII.)

The CHS Program has produced the first generation of hardware. The common computer hardware for the architecture includes a transportable computer unit (TCU), a portable computer unit (PCU), a handheld terminal unit (HTU), and a lightweight computer unit (LCU). The hardware is being procured in two versions; commercial grade (V1) and ruggedized (V2).[26] The first fielding of the common hardware did not, however, save the Maneuver Control System (MCS).

The original development effort within the Maneuver functional area of the ATCCS architecture was a cumbersome, bulky series of computers with ten generations of unsatisfactory software.

After the last of several prime contractors, despite six years of effort, was unable to achieve adequate performance levels the Maneuver Control System development effort was halted in February 1993.[27]

The MCS, as originally envisioned in the ATCCS architecture, was to have provided force level information for commanders and their staffs from the battalion/task force through corps level. The fatal flaw in this concept was that all information in the maneuver database and a good portion of the intelligence database was dependent upon human input at the battalion or original source level. The information requirements placed on the lowest level of the proverbial information "food chain" were exorbitant and did not benefit either the commander or the staff at that level.

The underlying causes for the failure of the MCS program were; a lack of automated information input to the MCS database, the inability of the MCS software to provide useful situational awareness information at battalion level, and the lack of a functional network architecture. MCS was not a system that would support information warfare.

A better solution was needed and was provided with the introduction of the automated input and display functions of the M1A2 tank. Though far from perfect and with no initial commonality, the M1A2 reoriented the development of the digital battlefield architecture from the bottom-up instead of from the top-down.

V.
EMERGING DOCTRINE

As the painful lessons of MCS were being learned the entire concept of command and control on the information battlefield was being reassessed within the Army's Training and Doctrine Command (TRADOC) based on the experiences of the Gulf War and the emerging information technologies.

In its 1993 version of *Field Manual (FM) 100-5 Operations* two new concepts were introduced. They are:

> • **Battle Command** - a combat function defined as the art of battle decision making, leading, and motivating soldiers and their organizations into action to accomplish missions. Includes visualizing current state and future state, then formulating concepts of operations to get from one to the other at least cost. Also includes assigning missions; prioritizing and allocating resources; selecting the critical time and place to act; and knowing how and when to make adjustments during the fight.[28]

> • **Battle Space** - a physical volume that expands or contracts in relation to the ability to acquire and engage the enemy. It includes the breadth, depth, and height in which the commander positions and moves assets over time. Battle space is not assigned by a higher commander and extends beyond a commander's AO. It is based on the notion that commanders expand their thinking to develop a vision for dominating the enemy and protecting the force before any mental constraints are imposed, such as overlays depicting phase lines, boundaries, and arrows.[29]

LTG Paul Funk explains the utility of battle space with the observation - "For a tool of war to be useful *it must be applicable throughout the chain of command* (emphasis added); for example it must be of value to the squad leader as certainly as it is to the division commander."[30] It is this need for usable information by every soldier and fighting crew, as well as the commanding officer, that drives the design of the organizations and systems to fight with information based tactics and doctrine. This does not mean that each recipient of information has the same information, only that he has the information he needs for his own situational awareness and decision making. Also inherent in the concept of battlespace is the massing of combat effects rather than the traditional physical massing of combat units.[31]

In his view of the Army of the 21st Century General Sullivan has stated.

> "The high ground is information. Today we organize the division around the killing systems, feeding the guns. FORCE XXI must be organized around information...The creation and sharing of knowledge followed by unified action based on that knowledge which will allow commanders to apply power effectively. The purpose of the FORCE XXI must be to dominate, to control, to win; information will be the means to a more powerful end. It is information-based battle command that will give us ascendancy and freedom of action.-- for decisive results -- in 21st Century war and operations other than war (OOTW)."[32]

This reorientation in operational concept has resulted in a radical change to the requirements document for the Army Tactical Command and Control System (ATCCS). The new requirement is for Army Battle Command Systems (ABCS) that expand the vision of ATCCS "...to include joint strategic connectivity, echelons above corps (EAC) and includes the operational and tactical systems extending from corps down to platform/section level."[33]

A new element was added to the organizational concept called Army Brigade and Below (AB2) Command and Control System which is described as "a suite of digitally interoperable, battlefield operating system specific functional applications, designed to provide near-real-time situational information to tactical commanders, on-the-move, down to platform/squad level."[34] These are the IVIS-like subsystems on each system that automatically generates most of the information for the ABCS database

All of these changes to introduce seamless information flow are designed to achieve force coherence through shared knowledge of battlefield conditions versus traditional physical means. Battle command in the future will require an acceptance that shared knowledge will be the principal means of exercising control of forces.[35]

The Army succeeded in accomplishing this force coherence in DESERT STORM by brute force and rehearsals, not by seamless information flow. The experiences of the 1st Brigade, 1st Infantry Division are fairly typical.

> "If the Army had 3d wave technology, it did not yet have 3d wave connectivity. For example, no system existed that linked national intelligence assets to tactical formations - thus enabling real-time transmission of critical combat information. In-flight reports and kindly commanders of allied units still proved a more reliable means of acquiring intelligence than did the Army's own intelligence system. Our system is still not designed to broadcast information, but rather to respond to inquiries."[36]

Battle Space and Battle Command are no longer the purview of battalion, brigade, division and corps commanders who were the sole recipients of information in the past and had the staffs to aid them in utilizing the information. Digitization, if applied correctly, has the potential to provide individual soldiers and crews with not only the effective firepower of much larger organizations but more significantly the knowledge base to coordinate and employ these fires. Individual vehicle commanders and squad leaders will be able to exercise battle command and control battlespaces that are geometrically greater than has ever been experienced before. This will require the development of new concepts and techniques for the coordination of fires and the demarcation of boundaries as individual vehicles move about the non-linear battlefield. This is the **revolutionary change brought about by digitization.**

The traditional chains of command will most likely not change; however, the knowledge base of the commander will be much greater and automation should result in significant decreases in the size of all staffs. The effectiveness, lethality and flexibility of soldiers and crews augmented with digital systems will be exponentially greater. Tactics and the methods of command and control may change as we experiment with new techniques of moving, distributing, and using the information base within and among digitized units. As more experience is gained with different organizations traditional units and certain organizational levels may be eliminated.

VI.
A NEW CONCEPT

In their paper Sullivan and Dubik describe the tremendous increases in dispersion and lethal ranges in an operational theater from antiquity to the Gulf War. The relative size and strengths of military organizations have not changed that much but their physical dispersion and the size of the battlefield has radically increased.[37]

There has not been as great a change in the close battle as one might expect. In ancient times soldiers fought at the half meter range of their swords; in DESERT STORM armored vehicles dueled at ranges from 2,500 to 3,000 meters (a 6,000 fold change). While the range of the close battle engagement was radically different the lateral dispersion between fighters grew proportionately less. In antiquity soldiers fought shoulder to shoulder (.5 meter/man) while in DESERT STORM four man tank crews habitually attacked with 50 meter intervals between vehicles (12.5 meters/man) only a 25 fold change.[38] Linear battles using the tactics of Baron von Steuben adapted for mounted warfare defined the close battle fights of DESERT STORM as battalions and brigades attacked on line with tanks abreast. These important points raise the third issue of digitization.

III. Intelligent soldiers, down to individually equipped infantrymen, manning digitized weapon systems with high situational awareness and firing precision munitions from multiple launching platforms are capable of massing combat effects without the need to physically mass on the battlefield.

As noted earlier, the M1A2 Abrams Tank and soon the M2A3 Bradley Fighting Vehicle, AH-64D Apache Longbow helicopter and RAH-66 Comanche helicopter weapon systems will become computer systems that are both autonomous and netted within an information network. They will digitally process and display information from their own internal sensors and processors as well as information from external sensors and processors in near real time. Through digital communications and display technology their crews will not have to look right and left to maintain orientation with other vehicles 50 meters away but will be able to move about on the battlefield with hundreds or even thousands of meters between vehicles and aircraft while the crew maintains a hemispherical situational awareness about them.

(Information Dominance + Smart Weapon Systems) =
Increased Situational Awareness =
Greater Autonomy =
Greater Dispersion

The capability of these systems to increase their lethality by having computers look through focal plane array sights and other sensors (on and off the vehicles) coupled with advanced fire control algorithms will give dumb bullets brilliant capabilities when launched from or controlled by brilliant systems. Additionally individual crews will have the potential to simultaneously control and employ multiple external weapons through digital linkages. The following scenario is possible before the year 2010 with systems in production or development today.

The Mission:

Destroy an enemy company that has occupied a defensive position 50 kilometers away. Establish a brigade passage point. On order pass the brigade through.

The Force:

- 3-M1A2 Abrams Tanks
- 2-M2A3 Bradleys (with 12 SIPE equipped infantrymen - 6 per vehicle)
- 2-M3A3 Scout Bradleys

•1- Bradley Fire Support Team Vehicle
•2-Bradley Stinger Teams
•1-M1064A3 120mm Mortar Team
•1-Breacher Combat Mobility Vehicle with accompanying engineer squad
•1-M4 Command and Control Vehicle (C2V)
•1-Force Logistic Package

The force will receive in direct support (DS) of its operation a four gun M109A6 Paladin howitzer section (or the advanced field artillery system (AFAS)), two RAH-66 Comanche helicopters, two AH64D Apache Longbows and two F15E Strike Eagle sorties.

The force commander receives the mission OPORD and graphics from the brigade commander via MCS in the C2V as he awaits the arrival of the brigade commander for a face-to-face discussion of the mission. While the commander is performing his mission analysis, the mission is retransmitted by the commander's radio-telephone operator as a warning order to each vehicle in the force, complete with graphics.

The commander displays his area of operations from the CD-ROM map file and overlays on it both the intelligence overlay he has just received with the OPORD and the last 24 hours worth of data on the area that was broadcast on the operations and intelligence (O/I) net from the brigade S-2's All Source Analysis System. This information was automatically stored on solid state and hard disk drive memory units[39] in the C2V as it was received. He displays this all on the large scale flat panel color display covering a wall in the C2V and determines his battle space.

While he is doing this the 1st Sergeant double checks the personnel, fuel, maintenance prognostics and ammunition status on each vehicle by remotely querying each vehicle's logistical data files.[40] Using the appliqué digital C2 kit in his M113A3, he totals the data and transmits it to the Supply Sergeant with the combat trains. After specifying the exact LOGPAC loads and the location and vehicle sequence for resupply operations he is then free to visit each vehicle and inspect/check each soldier personally with the force medics.

The scout section leader, upon receiving the warning order transmits a request which is routed through the force's C2V to brigade to receive all ASAS, J-STARS, RPV, Air Force Recce and national coverage for an area 10 kilometers in diameter around the objective area. This information will include all processed digital reports and digital photography. The digital imagery information will be routed to the Common Hardware mass memory storage devices on the M-4 C2V where the force commander and team leaders can view it and decide which images they wish to transfer to their own vehicles for use later.

He will then contact the DS Comanche team to coordinate his reconnaissance plan with the mission flight plan of the four helicopters. This coordination will include establishing data linkages to receive output from the Comanche's aided/automatic target recognition program that is coupled to the aircraft's 2nd generation focal plane array FLIR[41] and the targeting output from the Apache's millimeter-wave acquisition system. He arranges to receive processed target data only as the real-time video is not essential and is time consuming over the SINCGARS. He will, however, be able to pass essential still frame video as required during the operation.

The fire support team leader will make preliminary coordination with the DS artillery section and the mortar team leader receiving a complete listing of the round type and count on each gun/FAASV and establishing laser codes for all laser guided munitions. The OPORD will contain the common Hellfire laser codes for the operation so that he can properly laser designate targets for the Comanches. He will establish digital linkages with the Apaches to designate acquisition boxes for the millimeter wave seekers on the Longbow Hellfires. He will also transmit a message to brigade requesting call signs and frequencies for the F15E's which was not in the brigade order. He will also verify that the planes will be carrying AGM-130 munitions so that target coordinates can be sent directly from any combat vehicle to the aircraft where it can be programmed into the weapon and flown to that target location.[42]

The Stinger Team leader will tie into the air defense warning net through his Hand-held Terminal Unit (HTU) and EPLRS radios.

This will give him access to both the division's air defense sensor net and the AWACS data net. He will use the Terrain Evaluation Module intervisibility program to plot the most effective firing positions for supporting the attack. Once the firing positions are determined he will designate planning routes and way points for the two vehicles in the section that will then be loaded in the navigation systems of the vehicles giving the drivers visual steer-to directions during movement.

The tank and infantry teams will begin studying the terrain on the approach routes and objective by viewing it on the displays in their vehicles. They will do this by calling up the digital map database in the mass memory files. The team leaders will also put in requests for recent digital imagery of the objective area which will be routed to the nearest Joint Imagery Processing Center (JSIPS)[43] They should also be able to route a call through the Mobile Subscriber Remote Terminal (MSRT) telephone in the C2V to the nearest Joint battle damage assessment cell to get digital pictures from the armament delivery recording (ADR) system on the aircraft of any air strikes in the objective area during recent days.[44]

Once the commander has decided on a course of action he will prepare his operations order and operational graphics on the MCS device utilizing the OPORD software program.[45] Once complete he will call his team commanders and each of the DS team leaders together for a face-to-face orders brief. The Air Force pilots for the mission will participate via a video teleconference link via MSE after they have received the OPORD and the graphics. During the brief any changes to the plan or graphics can be instantly annotated. At the conclusion of the meeting the RTO will transmit the final order, graphics, photographs, and movement way points to each vehicle while the team leaders are returning to their respective vehicles.

A full scale rehearsal will be conducted later with each vehicle sitting in the assembly area. The crews will move through the digital rehearsal on the maps and pictures in their on board systems, similar to what they experience in the SIMNET system today, to practice the mission.

The team will move initially with two scout sections abreast (1 to 5 KM apart) each consisting of an M3A3 Cavalry Fighting Vehicle, a Comanche/Apache section and supported by two dedicated M109A6 Paladin howitzers following 5 KM in trail and 1 KM apart. The M1A2s, M2A3s, mortar, engineers and the M4 C2V will move generally on line 2 - 3 KM behind the scouts and .5 to 2 KM apart depending on the terrain.

In open desert this 20 ground vehicle force would cover an area 8x5 KM. This is a density of one vehicle for every 2 KM^2. In close terrain they could move in two single vehicle columns within mutually supporting distance of one another.

Each of the scout M2A3's, the Comanches and the C2V would act as fusion centers for intelligence. The Comanches would act as nodes in both the J-STARS net and within the force net for the processing and passing of data.[46] They would be processing detected targets or cueing for target detection with the 2nd generation focal plane FLIR's, CCD cameras or Longbow radar and comparing it to data in their memory units from previous intelligence reports. Additionally as the systems are moving they will continue to receive, process and display any intelligence data generated by external sensors. These sensors may also include remote devices and micro sensors that have been scattered about the area of operations by the thousands.

As an example, if an AWACS detects an enemy fighter or helicopter approaching the force's battle space, its location and track will be transmitted via JTIDS to the ADA battalion's command and control node. Once processed by the FAADS C2I software it will be retransmitted via either EPLRS or SINCGARS radio in digital format to the Bradley Stinger Vehicles with the force. This digital information will result in three actions: 1) The gunners will be cued and the Stinger pod and sights on the vehicles will be slewed in azimuth and elevation to put the approaching aircraft in their capture windows; 2) The stinger crew will get a graphical display of the aircraft's track on their HTU; and 3) The Bradley Stinger Vehicle's command and control software will automatically retransmit the digital track information over the force SINCGARS C2 net. The aircraft icon will appear on each of the IVIS or C2 displays on all vehicles. Commanders will be cued and then can press one button to have their weapon systems slewed onto the approaching target if SOP dictates.

Each of the enemy vehicles and many of the infantry fighting positions will have been precisely located during the intelligence preparation of the battlefield (IPB) process. As the force closes they are verified by the sensors on the scouts, the Comanches, and an RPV over flight. High resolution J-STARS synthetic aperture radar images[47] are down-linked to a Ground Station Module (GSM)[48] at brigade and the results then transmitted over the SINCGARS/MCS net. It may also be possible to receive digital pictures from an Advanced Tactical Air Reconnaissance System (ATARS) mounted on the supporting fighters.[49]

Although the force commander had designated known targets to specific weapon systems in the operations order, he will now verify last minute data. He will review, on the large screen display, the proposed firing position and target allocation of each weapon system from the plan, superimpose on it the current location of all verified targets and the actual location of his vehicles, change any targets and finally transmit his situational view of the battlefield to each of the crews. What then appears on each of the displays in the force, including the aircraft, is the best estimate of all known targets and enemy defensive information from the entire knowledge base. From this point the data will be updated from the direct fire engagements or spot reports generated within the force. The commander now moves from to the C2V to his command tank to oversee the close fight.

Once aboard the M1A2, the commander swipes his personal smart card[50] across the reader in the tank so that its IVIS system configures to his personal preferences for display settings and transmits a digital control message to all other systems. This message allows the commander's M1A2 to assume the net control function of the C2 database from the MCS device aboard the C2V.

The fire support team leader now orchestrates the indirect fire preparation of the objective. He will observe the action on the objective through a series of different sensors that he is coordinating and controlling. If a reconnaissance Remotely Piloted Vehicle (RPV) was available for the mission, control would be switched from the scouts to the fire support team leader. If remote sensors were employed, he would task them to do targeting and battle damage assessment.

The two fighters are instructed to launch and from a range of15 KM, release a guided AGM-130 missile at the two most critical enemy targets as designated by the force commander. These rounds will impact before the first artillery rounds. Since these bombs transmit a digital FLIR or TV picture to the aircraft during the last 20-30 seconds of flight a last minute digital view of the target area is available.[51] It could be transmitted by the aircraft to the C2V where the crew could do some quick analysis if its computers are loaded with the digital imagery analysis tool (DIVAT) software, a quick imagery exploitation program,[52] and then send these to each vehicle in the force including the fire support team.

Each of the four Paladins with its armored resupply vehicle prepares to fire from independent firing positions 15 to 18 KM from the objectives. Each gun, precisely located by GPS and its Modular Azimuth Positioning System, will fire six rounds at its assigned target to insure target kill.[53] Each crew will then disperse to a second firing position where they will repeat this sequence on four more targets all within 10 minutes. While the guns are moving to their second firing positions the Apaches will each launch four fire-and-forget Hellfire Optimized Missiles from 7-8 KM. These will be aimed at predetermined grid coordinates from the IPB and the fire support team leader's analysis. The millimeter wave seekers in the warheads will lock onto the precise targets during their terminal flight phase.[54]

The preceding sequence will happen before there is any line-of-sight contact by the attackers with the enemy on the objective. As the second artillery strike sequence is impacting, the air and ground scouts will move to positions where they can lock onto their respective targets to do battle damage assessment (BDA). They will send back spot reports after the crews and on-board acoustic, day, FLIR and MMW sensors have processed their observations. This information will change the enemy icon displays on all vehicles to indicate both killed and active targets. The assault element will begin converging on the objective area during this phase with specific targets now designated as navigational way points to control the assault.

Between 3 and 4 KM from the objective, vehicle commanders will designate the first targets for their gunners on the displays whether or not terrain intervisibility allows direct observation. Commander's independent 2nd generation thermal viewers on the tanks and Bradleys will be set to scan specific overlapping sectors oriented on their primary targets as control measures. When line-of-sight is achieved the flat panel displays will show automatically designated and classified targets utilizing software originally developed for the Line-of-Sight Anti-Tank (LOSAT) target acquisition program. Friendly vehicles will be identified on all displays by special icons. These icons will be generated by each vehicle after it has queried target vehicles with an encoded millimeter wave signal and received a positive response.

The force commander, after determining the amount of destruction on the primary objective, can now choose different indirect fire options. He can have each Paladin fire missions in dedicated support of individual vehicles during the assault or shift fires to dedicated support of the air and ground scout elements as they isolate the objective area. A combat vehicle or aircraft commander only needs to press a fire mission button every time his gunner or he lases to a target to fire a dedicated support mission. Rounds will impact from these dedicated missions in the time of flight plus 30 seconds from request making indirect fire almost as responsive as direct fire.

The mortar section at this point will be firing various types of multi-spectral smoke missions on specific targets tuned to obscure the optics of the enemy systems. It is also capable of firing STRIX homing anti-tank rounds[55] if a target is located deep in defilade.

The assault phase will begin at 3 KM or less depending on inter visibility and end approximately 1.5 KM from the objective when the last of the bunkered infantry positions are destroyed by tank and 25mm direct fire. During the one to ten minute assault each M1A2 and M2A3 will operate in a hunter-killer mode. Commanders using target finding programs will find targets on their viewers, designate for engagement by highlighting them, and gunners, augmented with through sight target gun laying programs, will destroy them at the rate of up to 10 targets per minute.

On the objective, two-man teams of infantrymen equipped with the fielded version of what is now called the Soldier Integrated Protective Ensemble (SIPE) will dismount. They will seek out and kill or capture any remaining enemy using thermal (FLIR), image-intensified (I^2), and acoustic sensors.[5 6]

While the force is consolidating on the objective, the Combat Mobility Vehicle crew and the engineer squad are physically clearing, digitally recording, and marking passage lanes for the brigade to pass through. As each lane is prepared the vehicle commanders transmit eight digit grid coordinates of the entrance and exit points as well as detailed graphics of the entire passage area. This message, routed through the force's C2V, is sent to the MCS device in the brigade TOC C2V and the brigade commander's Bradley via the MSE linkage. Once approved by the brigade commander, the information is automatically disseminated to every vehicle in the brigade which is moving in dispersed columns over several hundred square kilometers. The entrance and exit points of the various passage lanes simply become way points in the internal navigation plans for the various vehicles and the drivers will receive steer to vectors on their display panels as they approach the area.

The preceding is only a single example of what can be accomplished with a digitally integrated force. Specific outputs of various intelligence systems and their products were not discussed to avoid classification; however, their digital integration does not require any unique technical capabilities.

In this operation, mass was accomplished by the synchronization and concentration of fires on the enemy. Decisive victory was achieved by both individual crews and commanders employing digitized systems to outpace the decision cycles of their respective opponents. As certain opposing forces develop or purchase similar capabilities, tactics and techniques will need to be altered to retain the agility to remain within the enemy's decision cycle. This may require new systems, attacking his information systems or the restructuring of information architectures to retain the edge. Whichever solution or combination is required, we must build the flexibility into our systems to allow rapid change to be feasible.

VII.
COMMUNICATIONS CHALLENGES

Although the example cited in the previous section is achievable with today's technologies and capabilities there are many causes for concern. In addition to the three issues already discussed there is the ever increasing number of different requirements for communications capacity to handle the digital information flow.

IV. Communications capacity has become a critical path in digitization.

The fear in the communications, maneuver, and intelligence communities is that the demands of the ever increasing digital message loads on communications systems will be the limiting factor in digitizing the battlefield. This is particularly significant with the recent explosion in digital imaging capabilities.

In a paper on future digital battlefield data rate projections Howard and Evans estimated that a DESERT STORM-like force would generate data at the rate of 268 terabits/day or 6,600 megabytes/second.[57] In a companion study they concluded that, "existing wireless communications systems are adequate to support a digital battlefield, but not an optimal digital battlefield, because these systems impose some restrictions on the information that can be transmitted. This means that Corps and Army might know what's going on, but only highly filtered data will be available at the lower echelons."[58]

As was shown in Section IV. the backbone communications systems within the Army consist of the Mobile Subscriber Equipment area communications system, the Single Channel Ground and Airborne Radio System (SINCGARS) and the Army Data Distribution System (ADDS). In reality, the SINCGARS radio system has become the de-facto digital data communications system at the tactical level.

It is the only communications medium widely available at the tactical level and has been exploited for use through the development of modems that allow the computers to "talk" to one another over the radio. This severely limits the amount of data that can be exchanged as the radio's maximum digital transmission rate is currently 16 Kbps.[59] However, actual usable throughput has been found to be only about 4.8 Kbps with the IVIS equipped M1A2 tank. A block improvement to the SINCGARS is due in FY98 that will include a packet data appliqué to increase this capacity.[60]

The other element of forward, mobile tactical communications capability is the Enhanced Position Location Reporting System (EPLRS). It is the tactical part of the Army Data Distribution System (ADDS). This radio is designated as the primary data distribution system forward of the brigade area.[61]

Originally called the Position Location Reporting System (PLRS), it was originally designed to be a locating system that would calculate and transmit positional information. It was designed to do this on a common net that was different than the voice FM radio nets to both increase situational awareness and reduce FM voice radio traffic. Additionally PLRS was to serve as a lower level conduit for data transmitted over the Joint Tactical Information Distribution System (JTIDS) through interfaces located at the PLRS master units.[62] EPLRS is now the successor system. To accomplish the data communications function the basic PLRS was enhanced with the addition of a data distribution module.[63] It is a low capacity (4 Kbps) data communications system to carry data for the FAADC2I, AFATDS, ASAS systems and also to support MCS's digital communications needs.

The EPLRS interfaces with the Joint Tactical Information Data System (JTIDS) through the Army's Class 2M JTIDS ground terminal. This allows data connectivity on common JTIDS nets with Air Force and Navy command and control systems. The Airborne Warning and Control System (AWACS) provides aircraft tracking data via JTIDS to the Army air defense battalion's Air Battle Management Operations Center (ABMOC). In the ABMOC information is processed on a Common Hardware/Software computer then retransmitted to the appropriate ADA sensor C2 node via the ADA battalions C2 EPLRS net.[64] Here it is again processed on a CHS computer and combined with data collected by the sensors and retransmitted on a second EPLRS net to the ADA fire units.[65]

The EPLRS utilizes a technique called time division multiple access (TDMA). It operates in 800-microsecond bursts each containing 94 data bits. The TDMA net on which an EPLRS operates is divided into 64 "epochs." Each epoch is subdivided into 256 "frames" with each frame having 128 time slots. This gives the net controller 32,768 time slots to allocate to stations on the net during each 64 second period. Eighty bits of data (equivalent to 10 alphanumeric characters) can be transmitted during a single time slot.

A station is allocated different numbers of time slots on the net depending on its priority to transmit information and the amount of data it is required to transmit.[66] One station on the net can transmit at a time, but TDMA insures that each station gets its chance to speak on the net during its allocated periods. This solves a problem that occurs with other types of radios that must listen for net activity prior to transmitting. TDMA allows many virtually simultaneous data transfers to occur on a single net.

Acceptance of the EPLRS by both the user and development communities has been very poor. Although it has been repeatedly stated that EPLRS is the official tactical level data radio system, only the FAADC2I system has actually relied on it for its heavy division configuration design. The AD system remains unfielded due to slippage's in the EPLRS schedule and the first fielding of a FAAD C2 capability in a light division is using SINCGARS radios to move tactical level data. EPLRS was recently fielded to the 24th Infantry Division in its stand alone position locating mode but is apparently not being used as a digital communications carrier.[67]

The Army leadership has questioned the utility of the system and the Battle Lab at Ft. Gordon has begun experimenting with wireless area and wide band technologies to supersede the EPLRS.[68] The first demonstration of a wide band packet radio network using spread spectrum processing has recently occurred at Ft. Monmouth. The system individually addressed packets of data from one CHS computer, transmitted and routed the packets through the network on multiple paths and then reassembled them at the destination radio for use by a second computer. It achieved burst data rates of 100 to 400 Kbps operating over ranges from one to 10 KM.[69]

In the absence of any other near-term solution, the SINCGARS radio will remain the primary tactical data pipe for the short term. Innovative means are being found to utilize the limited capacity of the SINCGARS pipe.

Among these ideas is a mid-term solution called Integrated Data Transport System (IDTS). The concept is to "combine SINCGARS data and MSE packet network subsystems in an integrated system providing communications links to identified users throughout the region of conflict."[70] The keys to this system are the automation of the interface between the SINCGARS radio and the MSE system and the introduction of flood search routing within the MSE switching architecture. Basically what this system does is allow a computer, that is capable of transmitting data over a radio, to also transmit a telephone number in its message header. When the message is sent over the net one of the receiving radios on the net is a gateway station to the MSE system. The gateway recognizes the addressee as a telephone location and acts on it. The gateway temporarily stores the message in a buffered memory, dials through and transmits the message over the MSE telephone system. The system works in reverse by giving each radio on a net a sub-address of the phone number where the net gateway is located.[71]

Although this system will not help the intra-battalion transfer of data it will allow alternate means of automatically sending and receiving data between battalions and all levels of command above battalion. It will also require the development of a gateway that can accomplish this interface from a Mobile Subscriber Radio Telephone (MSRT) unit rather than at the MSE Small and Large Extension nodes (SEN and LEN). This is where this interface currently occurs with the manual Combat Net Radio Interface (CNRI). The interface at an MSRT is essential since this is the only MSE connectivity at battalion level. The system will still be limited by the digital throughput rates of the

MSE system (6 Kbps). However conference calls among computer systems is possible for data with multiple destinations.[72]

Another disadvantage of computers communicating data over radios as we currently do, is that only one machine can transmit at a time and the others must listen in a hierarchy. When a SINCGARS begins a transmission the net reaction time before another radio or recipient detects that transmission is .5 second. Only the #1 priority computer on a net can transmit instantaneously. The #2 computer always must listen for .5 second prior to transmitting to insure that the #1 computer has not just initiated a data broadcast. The #3 computer must always wait 1 second, etc. If there are twenty-five computers on a net, such as a battalion or brigade command net or the command net of the future force in Section VII., the #25 priority computer must always wait 12 seconds after it is ready to send data. It will frequently be preempted, resetting its listen-before-talk clock, if one of the other machines begins a message during that 12 seconds.[73] Future radios must solve this problem with some type of packet communications technology[74] or perhaps by a time slot allocation technique as is used with EPLRS and JTIDS.

Digital video imaging and the requirements to move large digital data files and images as part of command, control and intelligence operations is growing astronomically. The desire is to exploit data from multiple forward high resolution digital sensors by transmitting it back to large processors. The data is then fused with data coming in from other service and national systems to establish the most comprehensive intelligence estimate possible. This demand to move the data to the processors is creating a whole new communications load on the backbone systems.

The introduction of advanced sensors into weapon systems, such as digital 2nd generation, focal plane array FLIRS, millimeter wave radars and LADAR's is also adding to the information available for transmission and fusion. The installation of powerful on-board computers to perform automatic target tracking, locating, and recognition functions, is creating additional processed data from digital imagery. This data will also be transmitted over the tactical nets to command posts and analytical stations where it can be fused with other data or viewed in real-time to increase the situational awareness of the entire force not just the crew on the vehicle.

Some short term solutions have been found such as the Harris RF communications group's video imaging transmission device. It will transfer error-free, a digitally compressed, high resolution, full color, still frame image at 2.4 Kbps in approximately 90 seconds.[75] Another is the PhotoTelesis System demonstrated at Ft. Knox during the first Digital Battlefield Demonstration.[76] However, the need to transmit high volumes of still and eventually digital video imagery continues. Ninety seconds is an unacceptable transmission time for an image by factor of 100.

Currently the Army relies on the concept of disseminating both intelligence and imagery on a specific subscriber basis. The asynchronous transfer mode (ATM) technology mentioned in Section IV. as a possible solution to the protocol problem, also facilitates the precise delivery of data to a specific or multiple addressees anywhere in the network. It is probably the long term solution to the data movement problem.

The implementation of this technology; however, generates the requirement for communications systems that have bandwidths in the gigabit per second rate. In the commercial world AT&T has already designed a switch to operate on an ATM system at 662 gigabits per second.[77] AT&T can rely on high bandwidth transmission technologies such as fiber optic cables that are not available to a mobile force. Other ideas are needed to get information to users until large bandwidth systems are brought on line.

A new type of cellular satellite phone system is coming on line in the commercial market place that could be adapted and utilized in conjunction with MSE. The system consists of a geostationary satellite, called MSAT, and dual mode cellular phones that are capable with their 12-inch disk antennas of transmitting voice, data, and facsimile. These telephones can transmit directly to the satellite with an amplifier that fits in the trunk of a car. A single satellite can handle 3,200 simultaneous radio channels and the system is being designed for asynchronous data services.[78] A satellite could be deployed for area coverage of a theater and a mobile ground station could then act as a primary gateway into the MSE system. This system would act as a supplement to the MSE system bringing a data capable cellular telephone hook-up to each combat vehicle's data port.

Another approach to solving the information dissemination problem is to use broadcast technologies. By making large amounts of processed and unprocessed information widely available and relying on the recipients to sort through and manipulate the data with their own on-board processors a large portion of the bandwidth requirement goes away. GM Hughes Electronics launched a direct broadcast satellite in December 1993 with sixteen 120 watt transponders on it. The system is capable of transmitting millions of bits per second and requires only an 18-inch diameter antenna for reception. This is a commercial digital system designed to bring 100 channels of programming to individual subscribers.[79]

The C2V of the 2010 force could have a few stabilized satellite dishes on its roof and be receiving broadcast intelligence products including imagery, video and data files from the corps ASAS on one, and processed imagery with analysis from the theater Joint Service Imagery Processing System(JSIPS)[80] on a second. ASAS systems are already receiving and processing data distributed to them by broadcast systems.[81]

The above are but a few of the possible solutions that will insure that digitization of the battlefield is a reality by the early 21st Century. In the midterm, solutions will have to be found to allow digital operations over existing communications. This will include advances in video compression, packet switching technology and innovative methods of transmitting essential data elements. In the long term new communications systems will be required that include broadcast capabilities and ATM switching technologies from the commercial world.

VIII.
FUTURE WAR

> Be very careful how you design your machines. Remember you have the patent on the machine and the option to change it. God has the patent on man and he is not going to change his design.
>
> LTC Nicholas A. Andreacchio
> Commander, 2-77AR, 1977

Will all of this advanced information technology and digitization fundamentally change war as we know it?

Sullivan and Dubik conclude their paper on warfare in the 21st Century with the observation that three continuities exist in the nature of warfare:

> **1st; The future will differ little from the past with regard to the root causes of war.**
> **2nd; The nature of war remains a contest of wills where one group attempts to force its will on others.**
> **3rd; War demands both science and art from the leaders who wage it.[82]**

These three continuities remain because it is still people and not the technologies that determine the outcome of war.

Although this paper discussed a single, illustrative organizational change in combined arms forces there are obviously many other possible options. Digital technologies and the restructuring of the communications architectures to support them will provide numerous ways to organize for "conventional" combat in the future. They provide tremendous capability; however, they must be weighed carefully against their vulnerabilities.

The "warrior ethic" must now permeate the entire infrastructure. This is due to the exponential growth in the lethality of single individuals or crews whose effectiveness is based on digital capabilities, but dependent on inter-netted information databases. The entire organization must function as a symbiotic whole to produce the levels of information necessary to win on a battlefield that encompasses millions of square miles and billions of bits of data.

We have mastered the art and science of training the traditional warriors at the various training centers such as the NTC, CMTC, and JRTC. We must now train the entire force to this level of battlefield proficiency for it may not be on the front lines where battles and campaigns are fought and won. Information age warriors will have to deal with electromagnetic pulses, viruses and Trojan horses attacking their databases as well as artillery rounds bursting in the air.

In the future, as new enemies attempt to impose their will on our nation, they may not field Combined Arms Armies, Republican Guard Corps, or gangs firing volleys of RPG's. Instead we may see.

> "Small, highly mobile elements, composed of very intelligent soldiers armed with high-technology weapons, (who) may range over wide areas, seeking critical targets. Targets may be more in the civilian, rather than the military, sector. Front-rear terms will be replaced with targeted-untargeted."[83]

Aas we continue to modernize, digital technology is already changing the American way of war; however, the nature of war has not changed. The dangerous adversary of the 21st Century will not be one who attacks the technology or who develops other technologies, but the one who attacks the will to employ that technology effectively.

The microchip and information are revolutionary new capabilities to exploit. They may in fact, change the physical appearance of the future battlefield. In the end, however, it will be the leaders who can impose their will on their adversary by leveraging the technologies to influence the enemy's will to resist, not the devices themselves that will determine the victor.

E N D N O T E S

[1] General Gordon R. Sullivan and Lieutenant Colonel James M. Dubik, *Land Warfare in the 21st Century,* (Carlisle Barracks, PA: Strategic Studies Institute, 1993), 28.

[2] LTG(ret) Frederick J. Brown, *The US Army in Transition II,* (Washington: Brassey's, 1993), 4.

[3] COL John R. Boyd, *A Discourse on Winning and Losing,* Briefing paper, (August, 1987).

[4] Institute for Land Warfare Background Brief No. 58, *Army Issue: Digitization and the Modern Battlefield,* (Washington: Association of the United States Army,1993), 2-3.

[5] Alvin and Heidi Toffler, *War and Anti-War,* (Boston: Little, Brown & Co., 1993), 33-43.

[6] Ibid., 32.

[7] Sullivan and Dubik, iii.

[8] Ibid., 12.

[9] Michael J. Mazarr, *The Military Technical Revolution, A Structural Framework,* (Washington: Center for Strategic and International Studies, 1993), 1.

[10] John Arquilla and David Ronfeldt, "Cyberwar is coming!", *The Journal of Comparative Strategy,* Volume 12, No.2 (1993): 144?.

[11] General Gordon R. Sullivan, *America's Army , Into the Twenty - First Century,* (Cambridge, MA: Institute for Foreign Policy Analysis, 1993):14.

[12] Sullivan, 18-19.

[13] Department of the Army, *The Army Modernization Plan, Vol. II, Annex A,* (Washington: Department of the Army, January 1993): A-1.

[14] John W. Shannon and Gordon R. Sullivan, *Strategic Force - Decisive Victory, A Statement on the Posture of the United States Army Fiscal Year 1994,* (Washington: U.S. Department of the Army,1993): 68.

[15] MG's Jay M. Garner and Ronald V. Hite, *Horizontal Technology Integration (HTI) Concept Paper,* Memorandum, Washington, 8 November 1993.

[16] Toffler and Toffler, 189.

[17] Department of the Army, *The Army Enterprise Vision,* (Washington: Department of the Army, 1993): 9.

[18] Ibid., 18.

[19] Unisys Corporation, *Enterprise Integration: The Goals and Challenges of the Defense Enterprise Integration Services Program,* (McClean, VA: Unisys Corporation,1994).

[20] CECOM, *Plan for Implementing the MIL-STD-188-220 for Digitized Brigade '96 (WORKING DRAFT),* (Ft, Monmouth, NJ: CECOM, 21 January 1994): 1-2.

[21] Leigh Ann Klaus, "ATM - The Future of Battlefield Communications", *Defense Electronics* (January 1994): 26-28.

[22] Adrian Mello, ed., "Advertisement for MacLinkPlus", *MacWorld* (May 1994): 146.

[23] Sandra I. Meadows, "Molding Seamless Matrix is Pentagon's Next Target", *National Defense* (February 1994): 14.

[24] Stephen Budiansky, Bruce Auster, Joseph Galloway and Peter Green, "New Weapons of War" *U.S. News and World Report*, (May 31, 1993): 30-33.

[25] PEO Command & Control Systems Pamphlet, *ACCS, Command and Control for Today's Battlefield*, (Ft. Monmouth, NJ: 1992): 2.

[26] TRADOC System Manager for Multi-Functional Computers, "TSM-MFC Update," *Army Communicator*, (Summer 1993): 29.

[27] Neil Munro, "Budget Cut, Loss of Loral Contract Cloud ATCCS Future," *Defense News*. (March 1-7, 1993): 5.

[28] Department of the Army, *Field Manual (FM) 100-5 Operations* , (Washington: Department of the Army, 14 June 1993: Glossary-1.

[29] Ibid., 6-12.

[30] LTG Paul E. Funk, "Battle Space: A Commander's Tool on the Future Battlefield," *Military Review*, (Leavenworth, KS: December 1993): 43.

[31] BG Lon E. Maggart and COL Gregory Fontenot, "Breaching Operations: Implications for Battle Command and Battle Space," *Military Review*, (Leavenworth, KS: February, 1994): 20.

[32] GEN Gordon R. Sullivan, "Building the force for the 21st Century -- FORCE XXI," MSG, Headquarters Department of the Army, (Washington: 081145Z Mar 94), 3.

[33] MG Larry G. Lehowicz, "Army Battle Command Systems (ABCS) Operational Requirements Document," memorandum for Commander, U. S. Army Training and Doctrine Command, (Ft. Leavenworth, KS: 24 December 1993), 1.

[34] Ibid., 7.

[35] GEN Frederick M. Franks, " A Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century," *TRADOC Pamphlet 525-5 (DRAFT)*, (Ft. Monroe, VA: 20 December 1993), 44-46.

[36] Maggart and Fontenot, 34.

[37] Sullivan and Dubik, 12-14.

[38] Tom Carhart, *Iron Soldiers*, (Pocket Books, NY: 1994), 28.

[39] Deborah Fowler-Shock, ed., *LCU Update*, SAIC Corp., (San Diego, CA: July-September, 1993), 1-8.

[40] MAJ Orlando Illi, "Maintenance Technology Sensor AI Communications Integrated Maintenance System (SACIMS)," Briefing Charts, U.S. Army Ordinance Center and School, Knowledge Engineering Group, (Aberdeen, MD: May 1993).

[41] John Boatman, "Production Funds for Comanche Restored," *Jane's Defense Weekly*, (London: January 30, 1993), 8.

[42] Debra Polsky Werner, "With Advances, New Weapons Only Get Smarter," *Defense News*, (Washington: February 7-13, 1994), 14

[43] Robert L. Davis, "An Overview of the Joint Service Imagery Processing System," *Journal of Electronic Defense*, (Washington: December 1992), 44-48.

[44] MAJ Richard D, Borenstein, "Visual Information Takes Flight in the Air Force," *Signal*, (Washington: May 1992), 41.

[45] OPORD Fact Sheet, distributed by Martin Marietta Corp., 1993.

[46] J. R. Wilson, "But Can It Win a Budget War?" *Armed Forces Journal International*, (Washington: April, 1994), 36.

[47] Stephen M. Hardy, "Battle Tested and Then Some," *Journal of Electronic Defense*, (Washington: June 1993), 62-67.

[48] COL Mendel S. Solomon, "The Army's Common Ground Station of the Future," *Journal of Electronic Defense,* (Washington: October,1990), 45-50.

[49] Martin Marietta Technologies Inc., "A White paper Discussion of Target Information That Can Be Made Available for Targeting and Tactical Reconnaissance Systems," (Orlando, FL: February 18, 1994), 4.

[50] Paula A. Gould and Beverly T. Schaefer, "Integrated Circuit Device Enables Immediate Information Access," *Signal,* (Washington: April, 1993), 55-58.

[51] Debra Polsky Werner, 14.

[52] Nancy Buchanan, "ESL's Full-Motion 'MacCombat Battle Assessment' Tool," *Armada,* (March, 1994), ???

[53] Glenn W. Goodman, "US Army Cannons Forced to Shoot and Scoot Until 2003," *Armed Forces Journal International,* (Washington: February, 1992), 45.

[54] "Optimized Hellfire Development," *International Defense Review,* (London: 4/1990), 447.

[55] FFV Ordnance, "STRIX," Advertisement in *Defense News,* (Washington: August 20, 1990),13.

[56] Carol Fitzgerald, Patrick Snow and Cynthia Mooney, *Soldier Integrated Protective Ensemble Advanced Technology Demonstration,* USA Natick RD&E Center, (Natick, MA, 1992), 19.

[57] William E. Howard III and Dennis K. Evans, *Digital Battlefield Projections (1992-2010),* Paper for the Assistant Secretary of the Army for Research, Development and Acquisition, (Washington: August 6, 1993), 3.

[58] William E. Howard III and Dennis K. Evans, *Technology for the Digital Battlefield,* Paper for the Assistant Secretary of the Army for Research, Development and Acquisition, (Washington: August 6, 1993), 2.

[59] ITT Defense, " ITT is SINCGARS," Product Brochure from ITT Aerospace/Communications, (Ft. Wayne, IN: May, 1991), 2.

[60] Robert K. Ackerman, "Coordinated Modernizations Spur Army Communications," *Signal,* (Washington: November 1993),34.

[61] Clarence A. Robinson, Jr., "Army's Digital Devices Move Presses Tactical Automation," *Signal,* (Washington: November,1990), 26.

[62] C3I Fact Sheet, "Army Data Distribution System," *C3I Yearbook,* (????:1988), 96-97.

[63] Glenn W. Goodman, Jr., "New Army Digital Data Radios on Track as EPLRS Overcomes Problems," *Armed Forces Journal International,* (Washington: May 1990), 78.

[64] JTIDS Project Staff, *JTIDS Overview Description,* MITRE Corp. document, (Bedford, MA: February 1993), 101-105.

[65] MAJ. Tim Ino, FAAD C2 Product Manager's Office, Huntsville AL, PHONECON 170013 April 94.

[66] James W. Rawles, "EPLRS: Accurate, Integrated and Secure C2 Link," *Defense Electronics,* (Englewood, CO: June,1990), 61-63.

[67] Clarence A. Robinson, Jr., "Modern Battlefield Demands Digital Data at Gigabit Rates," *Signal,* (Washington: November, 1993), 53.

[68] Thomas L. Phillips, ed., "Army Decision on Future of EPLRS Expected Soon," *C4I News,* (Potomac, MD: march 17, 1994), 2-3.

[69] Paul Sass and Ingrid Eldridge, "Army Demonstrates Wideband On-the-Move Communications for the Battlefield," *Signal,* (Washington: March 1994), 55.

70 Mark Tapscott, "SINCGARS Upgrades Moving to Full Battlefield Communications," *Defense Electronics,* (Englewood, CO: January,1993), 30.

71 Clarence A. Robinson, Jr., "Army Confronts Issues, Gains Information Flow," *Signal,* (Washington: April, 1993), 29.

72 Tapscott, 31.

73 Alfred Grasso, "Combat Net Radio (CNR) Protocols: A Means for Battlefield Digitization," *MITRE Corporation Study,* (Eatontown, NJ: 16 November, 1993), vii.

74 Robinson, "Army's Digital Devices Move Presses Tactical Automation," 27.

75 Clarence A. Robinson, Jr., "Small Mobile Devices Link Army Combined Arms Team," *Signal,* (Washington: November,1993), 62.

76 Sean D. Naylor, "Info War 'Digitization' Will Shape How Future Wars are Fought," *Army Times,* (Springfield, VA: May 17, 1993), 13.

77 Niel Gross and Peter Coy, "The Ideal Interchange for the Data Superhighway," *Business Week,* (New York: October 11, 1993), 116.

78 Clarence A. Robinson, Jr., "Dual-Mode Mobile Phones Couple Remote Rural Areas," *Signal,* (Washington: April,1994), 23-26.

79 Clarence A. Robinson, Jr., "Video Compression Coaxes Direct Broadcast Satellites," *Signal,* (Washington: April,1994), 29.

80 Robert L. Davis, An Overview of the Joint Service Imagery Processing System," *Journal of Electronic Defense,* (Washington: December,1992),44-48.

81 Ackerman, 34.

82 Sullivan and Dubik, 25-26.

83 William S. Lind, CAPT John Schmitt, COL Keith M. Nightengale, COL Joseph W. Sutton, and LTC G. I. Wilson, "The Changing Face of War into the Fourth Generation," *Military Review,* (Leavenworth, KS: October, 1989), 6.

BIBLIOGRAPHY

Ackerman, Robert K. "Coordinated Modernizations Spur Army Communications," Signal. (Washington: November 1993):31-35.

Arquilla, John and David Ronfeldt, "Cyberwar is coming!" The Journal of Comparative Strategy. Volume 12, No.2 (1993).

Boatman, John. "Production Funds for Comanche Restored." Jane's Defense Weekly. (London: January 30, 1993):8.

Borenstein, MAJ Richard D. "Visual Information Takes Flight in the Air Force." Signal. (Washington: May 1992): 41.

Boyd, COL John R. A Discourse on Winning and Losing. Briefing paper, August, 1987.

Brown, LTG(ret) Frederick J. The US Army in Transition II. Washington: Brassey's, 1993.

Buchanan, Nancy. "ESL's Full-Motion 'MacCombat Battle Assessment' Tool." Armada. (March, 1994).

Budiansky, Stephen, Bruce Auster, Joseph Galloway and Peter Green, "New Weapons of War." U.S. News and World Report. (May 31, 1993): 30-33.

Carhart, Tom. Iron Soldiers. Pocket Books, NY: 1994.

CECOM. Plan for Implementing the MIL-STD-188-220 for Digitized Brigade '96 (WORKING DRAFT). Ft, Monmouth, NJ: CECOM, 21 January 1994.

Davis, Robert L. "An Overview of the Joint Service Imagery Processing System." Journal of Electronic Defense. (Washington: December 1992): 44-48.

FFV Ordnance. "STRIX." Advertisement in Defense News. (Washington: August 20, 1990):13.

Fitzgerald, Carol, Patrick Snow and Cynthia Mooney. Soldier Integrated Protective Ensemble Advanced Technology Demonstration. USA Natick RD&E Center, Natick, MA, 1992.

Fowler-Shock, Deborah ed. LCU Update SAIC Corp., San Diego, CA: July-September, 1993.

Franks, GEN Frederick M. " A Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century," TRADOC Pamphlet 525-5 (DRAFT). Ft. Monroe, VA: 20 December 1993.

Funk, LTG Paul E. "Battle Space: A Commander's Tool on the Future Battlefield," Military Review. (Leavenworth, KS: December 1993): 36-47.

Garner, MG Jay M. and MG Ronald V. Hite. Horizontal Technology Integration (HTI) Concept Paper. Memorandum, Washington, 8 November 1993.

Goodman, Glenn W. Jr. "New Army Digital Data Radios on Track as EPLRS Overcomes Problems," Armed Forces Journal International. (Washington: May 1990):78.

_______. "US Army Cannons Forced to Shoot and Scoot Until 2003." Armed Forces Journal International. (Washington: February, 1992): 45.

Gould, Paula A. and Beverly T. Schaefer. "Integrated Circuit Device Enables Immediate Information Access." Signal. Washington: April, 1993: 55-58.

Grasso, Alfred. "Combat Net Radio (CNR) Protocols: A Means for Battlefield Digitization." MITRE Corporation Study. (Eatontown, NJ: 16 November, 1993).

Gross, Niel and Peter Coy. "The Ideal Interchange for the Data Superhighway." Business Week. (New York: October 11, 1993): 116.

Hardy, Stephen M. "Battle Tested and Then Some." Journal of Electronic Defense. (Washington: June 1993): 62-67.

Howard, William E. III and Dennis K. Evans. Digital Battlefield Projections (1992-2010). Paper for the Assistant Secretary of the Army for Research, Development and Acquisition, (Washington: August 6, 1993).

_______. Technology for the Digital Battlefield. Paper for the Assistant Secretary of the Army for Research, Development and Acquisition, (Washington: August 6, 1993).

Illi, MAJ Orlando. Maintenance Technology Sensor AI Communications Integrated Maintenance System (SACIMS). Briefing Charts, U.S. Army Ordinance Center and School, Knowledge Engineering Group, Aberdeen, MD: May 1993.

ITT Defense. ITT is SINCGARS. Product Brochure from ITT Aerospace/Communications, Ft. Wayne, IN: May, 1991.

Institute for Land Warfare Background Brief No. 58. Army Issue: Digitization and the Modern Battlefield. Washington: Association of the United States Army, 1993.

JTIDS Project Staff, JTIDS Overview Description. MITRE Corp. document, Bedford, MA: February 1993.

Klaus, Leigh Ann, "ATM - The Future of Battlefield Communications." Defense Electronics. (January 1994):25-45.

Lehowicz, MG Larry G. "Army Battle Command Systems (ABCS) Operational Requirements Document." Memorandum for Commander, U. S. Army Training and Doctrine Command. Ft. Leavenworth, KS: 24 December 1993.

Lind, William S., CAPT John Schmitt, COL Keith M. Nightengale, COL Joseph W. Sutton, and LTC G. I. Wilson, "The Changing Face of War into the Fourth Generation," Military Review. (Leavenworth, KS: October, 1989): 2-11.

Maggart, BG Lon E. and COL Gregory Fontenot, "Breaching Operations: Implications for Battle Command and Battle Space." Military Review, (Leavenworth, KS: February, 1994): 19-35.

Martin Marietta Technologies Inc. A White paper Discussion of Target Information That Can Be Made Available for Targeting and

Tactical Reconnaissance Systems. Orlando, FL: February 18, 1994.

Mazarr, Michael J. The Military Technical Revolution. A Structural Framework. Washington: Center for Strategic and International Studies, 1993.

Meadows, Sandra I. "Molding Seamless Matrix is Pentagon's Next Target." National Defense. (February 1994):13-14

Mello, Adrian, ed. "Advertisement for MacLinkPlus", MacWorld. (May 1994): 146.

Munro, Neil, "Budget Cut, Loss of Loral Contract Cloud ATCCS Future," Defense News. (March 1-7, 1993): 5.

Naylor, Sean D."Info War 'Digitization' Will Shape How Future Wars are Fought," Army Times. (Springfield, VA: May 17, 1993), 13.

PEO Command & Control Systems Pamphlet. ACCS. Command and Control for Today's Battlefield. Ft. Monmouth, NJ: 1992.

Phillips, Thomas L. ed., "Army Decision on Future of EPLRS Expected Soon," C4I News.(Potomac, MD: march 17, 1994): 2-3.

Polsky-Werner, Debra. "With Advances, New Weapons Only Get Smarter," Defense News. (Washington: February 7-13, 1994): 14

Rawles, James W. "EPLRS: Accurate, Integrated and Secure C2 Link," Defense Electronics.(Englewood, CO: June,1990): 61-68.

Robinson, Clarence A. Jr. "Army Confronts Issues, Gains Information Flow." Signal. (Washington: April, 1993). 29-30.

________. "Army's Digital Devices Move Presses Tactical Automation." Signal. (Washington: November,1990): 25-32.

________. "Dual-Mode Mobile Phones Couple Remote Rural Areas," Signal. (Washington: April,1994), 23-26.

________. "Small Mobile Devices Link Army Combined Arms Team," Signal. (Washington: November,1993): 61-63.

________. "Modern Battlefield Demands Digital Data at Gigabit Rates." Signal. (Washington: November, 1993):51-54.

________. "Video Compression Coaxes Direct Broadcast Satellites," Signal. (Washington: April,1994): 29-30.

Sass, Paul and Ingrid Eldridge. "Army Demonstrates Wideband On-the-Move Communications for the Battlefield." Signal. (Washington: March 1994): 54-55.

Shannon, John W. and Gordon R. Sullivan. Strategic Force - Decisive Victory. A Statement on the Posture of the United States Army Fiscal Year 1994. Washington: U.S. Department of the Army, 1993.

Solomon, COL Mendel S. "The Army's Common Ground Station of the Future." Journal of Electronic Defense. (Washington: October,1990): 45-50.

Sullivan, GEN Gordon R. America's Army . Into the Twenty-First Century. Cambridge, MA: Institute for Foreign Policy Analysis, 1993.

________. Building the force for the 21st Century -- FORCE XXI. MSG, Headquarters Department of the Army, Washington: 081145Z Mar 94.

Sullivan, GEN Gordon R. and LTC James M. Dubik. Land Warfare in the 21st Century. Carlisle Barracks, PA: Strategic Studies Institute, 1993.

Tapscott, Mark. "SINCGARS Upgrades Moving to Full Battlefield Communications." Defense Electronics. (Englewood, CO: January,1993): 29-32.

Toffler, Alvin and Heidi. War and Anti-War. Boston: Little, Brown & Co., 1993.

TRADOC System Manager for Multi-Functional Computers. "TSM-MFC Update." Army Communicator. (Summer 1993):29-30.

Unisys Corporation. Enterprise Integration: The Goals and Challenges of the Defense Enterprise Integration Services Program. McClean, VA: Unisys Corporation,1994.

U. S. Department of the Army. Field Manual (FM) 100-5 Operations. Washington: Department of the Army, 14 June 1993.

________. The Army Enterprise Vision. Washington: Department of the Army, 1993.

________. The Army Modernization Plan. Vol. II, Annex A, Washington: Department of the Army, January 1993.

Wilson, J. R. "But Can It Win a Budget War?" Armed Forces Journal International. (Washington: April, 1994): 36.