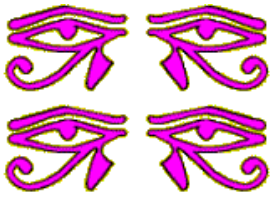

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How Much for a Pound of Communication?

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STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY.

EXECUTIVE SUMMARY

Title: How Much for a Pound of Communications?

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Thesis: Did historical advances in communication technology drive changes in the Command, Control and Communication architecture in use by the Ground Force components of Marine Corps forces? How should today's communication technology affect existing communication architecture doctrine?

Discussion: How much is a pound of communication worth to a warfighter? No communication is disastrous; as would be a budget containing only communication purchases. Where is the balance between proper coordination and "all talk, no fight?" Understanding communication equipment use requires the understanding of the strategy of its employment.

This paper evaluates the evolution of military communication architectures for the last fifty years. Through this analysis a methodology for implementing communication technology advances should be evident.

Conclusions: The Ground Component of Marine Corps forces, at the regiment and below, uses the same communication architecture as in World War II. However one fundamental principle (analog) used by all military radios did not change. Today we face a revolution in communication technology, digital communication. Digital communication techniques may replace fifty years of analog improvements. Consider how digital compact disks virtually eliminated the analog phonograph record industry.

Recommendations: Use commercial, digital, satellite communication equipment along with existing military equipment. Implementing the fruits of the commercial market advances can provide both an edge and a gap filler for military communication.

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the least, the enlightening and thoughtful reviews by Major Ronald Zich and Dr. Judith S. Ruud. All errors remain my own.

Paul E. Ruud

Lieutenant Commander, US Navy.

16 April 1997

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CHAPTER 1

Introduction

Communication plays a key role on the battlefield, from the advanced flag signals of Ghengis Khan to Desert Storm's Super High Frequency digital satellite links. From the beginning of warfare communication served three basic functions: convey orders to subordinates, convey information to superiors and control supporting efforts. Monumental changes to warfighting methods and communication ability occurred in the last fifty years. However, as this paper will show, the same organizational and communication structure remained.

a) Conclusions

The commercial music industry presents a good analogy to the situation faced by military communicators today. For most of this century acoustic recording was done using methods that represented sound waves with material (phonograph) or electrical (tape) images. The method of transforming acoustic or visual information into direct "images" is termed analog. In the 1980's digital technology (compact disk) replaced the entire phonograph and much of the tape industry. In spite of the many remarkable improvements to analog recording, digital quickly replaced it. The revolutionary principle behind digital recording allowed the quick replacement. Military communication still relies on analog principles, very similar to those of World War II.

CD's replaced phonograph records because digital technology inherently rejects noise whereas analog technology inherently retains it. This change in the fundamental nature of recording fueled a revolution in the music industry. So too can digital technology revolutionize military communication. Digital communication not only rejects noise, it also can be digitally controlled. Digital systems reduce both noise and human intervention. Many of the mundane operations done by human operators can be shifted to digital control systems, freeing the operators for tasks that require more thought.

Digital communication may yet change the basic conduct of war, however in the near term it may make the communication structure more able to fit the Operations Other Than War (OOTW) needs. The physical logistic and force protection requirements dictate a hierarchical military structure, as does information management. A single individual is not able to completely manage all details of a major operation. Therefore a structure is necessary to provide filters and to share the effort, while remaining under a single unifying command. In OOTW scenarios small teams operating under a large organization may require access to high levels of command or may be widely separated from the main body of the force. In these situations digital communication can create ad hoc communication structures that allow a commander to customize the command without major equipment changes.

Digital communication, supported by satellite networks, add flexibility and coverage to the military communication structure. New near earth satellites use capabilities developed for cellular phones to provide true global coverage. The new systems allow a single soldier to carry some of the communication abilities previously held at much higher levels of command. These new abilities may allow smaller teams to use fire control and coordination functions now performed at higher levels. Having the ability to use indirect fire may allow smaller teams to perform both infiltration type missions yet bring massed firepower when necessary. Communication advances may not change the conduct of war, but the advances fill in the communication necessary when a single soldier can affect the course of a nation.

How much is a pound of communication worth to a warfighter? No communication is disastrous; as would be a budget containing only communication purchases. Where is the balance between proper coordination and "all talk, no fight?" Understanding communication equipment use requires the understanding of the strategy of its employment. Although the communication structure at higher command levels evolved considerably in the last fifty years, the ground force lower level structure is essentially unchanged. Implementing the fruits of the commercial market advances can provide both an edge and a gap filler for military communication.

b) Thesis Design

The communication revolution affects all levels of the military command structure. Most federal communication providers market for the focal points of command, as this is the most communication intensive portion of the military structure. Yet many commercial communication advances are directed to the individual consumer. This paper will focus mainly on the lower level of the command structure that is similar to the target market of the commercial systems. Also, because the commercial market is hard to predict, this paper only considered demonstrated (but not necessarily fully fielded) commercial products that could be incorporated into the military within the typical five to ten year procurement cycle.

With the demise of the Soviet Union as a peer competitor, most of the predicted military operations will be small and expeditionary in nature. These small operations will mostly be conducted by the Marine Corps ground troops that can provide the small scale, rapid and flexible response needed for expeditionary operations. These type of operations match well with the advances in communication technology. Therefor this paper focuses on the communication needs of the Marine Corps. Because the Marine Corps' mission includes the requirement for major amphibious operations, any communication system used by the Marine Corps must also include the ability to support an amphibious operation.

To support the conclusion that no change occurred in the basic use of communication since before World War II this paper analyzes three historical eras. Each era contained both major advances in communication technology and an amphibious operation. The operations and eras are: Operation Forager, 1945; Operation Starlite, 1965 and Operation Desert Storm, 1990 or current doctrine. The communication structure of each era is analyzed in terms of the number of nets, area of operations, ratio of radios to personnel, level of command with radio communication. The characteristics of the structure for each era is analyzed for reliability, security, data rate, people and weight.

c) Historical summary

The age of electronics dawned somewhere between World War I and II. When vacuum tubes replaced the enormous electro-mechanical machinery used for communication, portable amphibious radio equipment became a reality. There are three main milestones of electronics technology: vacuum tubes, solid state transistors and integrated circuits. During World War II the vacuum tube ruled the day with power hungry radios eating batteries (when the salt water didn't short them out). The Vietnam War saw the introduction of solid state transistors and a subsequent improvement in size, battery use, range and reliability. The platoon commanders and their seniors still carry an instrument capable of communication with aviation elements and other fire coordination platforms. At the tactical level we use the same basic procedures today as in the Vietnam War, although technology advances provide a lighter, rugged system with greatly improved security.

Evaluating a span of over fifty years reveals little change in the aspects of the nature of war. Uncertainty rules the field, so reducing the fog of war is a force multiplier to any commander. War is still the

imposition of one commander's will on another by force. However, technology changed the face of war. The effects of technology fall into three categories: speed, lethality and area of coverage. For example the 1965 Operation Starlite in Vietnam and the 1945 Operation Forager in Saipan covered about the same area, however, Operation Forager needed three divisions while Operation Starlite needed three battalions. Clearly several factors, including the smaller opposition force in Vietnam, drove the smaller force size. However, the fact that three battalions cleared the same amount of ground as three divisions gives an indication of the changes in fighting force capability. Desert Storm further continues the trend of less force per unit of area.

Answering the question of how historical changes in technology affect communication creates a "chicken or the egg" dilemma. One main focus of exercises such as Hunter Warrior are to evaluate the effectiveness of new communication technology on the coordination and lethality of a force using it. Did more effective communication allow the greater range of operations or did the increased force mobility make more effective communication a necessity? The catch phrase of "shoot, maneuver and communicate" captures the idea that lethality, maneuverability and connectivity tie together and exist in balance for an effective fighting force. Evaluating this trinity's evolution from a communication perspective helps answer the question of "How much for a pound of communication?"

d) Changes in the World and the Way We Fight

...[T]he strategic role of the Marine Corps remains constant: to provide a strong expeditionary force-in-readiness that is versatile, adaptable, and powerful....[T]he Marine Corps will leverage its recognized skill of innovation to vigorously seek out new opportunities to enhance its usefulness, flexibility, and unparalleled expeditionary capability across the entire spectrum of contingencies.

This statement from the 1996 USMC Concepts and Issues paper sets forth the mission of the Marine Corps. The following Naval Department doctrine, stated in "Forward ...From the Sea" , complements the USMC mission.

...[A] change in focus and, therefore, in priorities for the Naval Service away from operations on the sea toward power projection and the employment of naval forces from the sea to influence events in the littoral regions of the world[.]

The two key focus areas are littoral regions and different levels of hostilities. Dealing with a less than total war significantly impacts the command and control of military forces. Littoral regions of the world, the focus of most activities, contain many urban regions that fill the radio spectrum. The military force operating in such an environment must modify their command and control structure to account for the fact that forces will tend to be smaller, widely dispersed and subject to a congested communication spectrum.

The generally superior logistics and communication capability of the US military combined with the rapid response capability of the USMC are key drivers in the National Command Authorities' selection of

the Naval Department for an operation. However the USMC communication equipment at the lower command levels are short range equipment, more useful for concentrated forces. A shortcoming of this communication structure is that it is not optimal for Low Intensity Conflict or Military Operations Other than War where the forces might not concentrate as they would on a traditional battlefield.

The conflicts of the next ten years need a communication structure that supports dispersed forces. However, the consequences of not being prepared to fight a major battle forced the communication structure in existence today. Emerging technology can support the dispersed force requirement while the existing equipment can be retained to support a major operation.

CHAPTER 2

ANALYSIS

a) Rationale -- "a pound of communication"

The challenge of military logistics is to offset the value of a particular item with the cost of getting it to the battle and supporting it. Communication equipment is not exempt from this rule. A limitation for proper communication analysis is that it neither shoots nor moves forces, and commanders seldom clearly understand communication. This limitation clouds any cost benefit analysis applied toward communication. Even Marine Corps manuals recognize this limitation:

Very few field commanders would consider a tactical maneuver which would cause his unit to exceed the range of his logistical support....But, due to lack of understanding of communications ...commanders pay very little attentions to the limitations of radio communications when developing their tactical scheme of maneuver.

Because of the tremendous advances in the field of communication technology using new communication capability requires innovative analysis. The fast pace of telecommunication technology advances creates a difficult, nearly impossible task for the military doctrine writer. Because the government market is a small fraction of the commercial communication sector, it has little impact on corporate decisions. At best, corporations engineer existing technology to meet military reliability specifications. Even in World War II, forces used commercial technology directly; for instance, Army troops in Italy used FM Motorola police radios. Fortunately, American industry explores all markets, essentially dragging military procurement along with it through various means of influence. A systematic comparison of technology and military use of that technology provides a sense of how to apply technology changes.

Communication procedures and equipment coexist in the "architecture." The term refers to a group of radios set up to communicate with each other. Evaluating changes to nets and their employment provides one way to determine how new technology affects military command structures. Evaluating the effect of technology on the communication architecture over the three eras described above divides into four main

areas: number of nets and their capacity; area of the operation; number of users versus the total force; levels of command with communication capability. Other factors influenced the operation of the architecture: reliability, security, bandwidth use and personnel. The intent is not to reproduce here an exhaustive reproduction of historical communication architectures. The focus is on significant modifications to amphibious command and control that arise from changes in communication technology.

b) Architecture Analysis

1) Number of nets:

Definition: A net is an organization of stations capable of intercommunications on a common channel or frequency. Comparing the number of nets established for a force with the size of the force indicates the amount of direct control deemed necessary by the commander of the force.

Discussion: This metric is important to get a sense of what is necessary to provide the commander the necessary communication paths needed to conduct the operation. The information for this metric is

[1945 - SAIPAN, OPERATION FORAGER; 1965 - VIETNAM, OPERATION STARLITE; 1992 - DOCTRINE]

Figure 1

Average number of Personnel Using a Net

derived from doctrine, operation plans and equipment characteristics. Because nets may have differing levels of usage, the author relied upon the anecdotal data contained in after action reports to validate the assumption that the operation plan contained sufficient nets to control the forces. The data are divided into two groups: 1) all nets and 2) command nets. Command nets indicate the portion of the architecture devoted to commanding forces, versus how much is needed for coordination to properly complete the commander's orders.

Significant Finding: The ratio of personnel to command net dropped about 30 percent in the fifty years following World War II. Considering that some command nets changed from wire to radio links, this indicates that the command structure remained about the same. With the exception of Operation Starlite the coordination nets followed the same pattern. One possible reason for proportionally more nets during Operation Starlite is that it was a much smaller operation. Unlike a larger force, the forces during Operation Starlite could use more coordination circuits without impacting the radio spectrum. Reducing wire use and other means of communication is indicative of the attention placed toward providing the means for rapid command and control of the operation. Mobile radios allow forces to communicate their situation without returning to a base. The shift to mobile radios indicates the commander's need for timely information. Increasing the number of mobile reporting stations, while adding to command post

complexity, reduces the "friction" by cutting down the reporting time for changing battlefield conditions.

2) Area of the operation:

Definition: This is the ratio of the number of personnel to the size of the area of operations.

Discussion: The enemy forces, unit mission, firepower, mobility and communication all affect operation area. With the preceding taken into consideration, it is impossible to say simply that communication alone allows a force to cover more area. Delivering the necessary lethality where appropriate is the key to defeating an enemy. Technology provides greater firepower, more mobility and more communication. To isolate the effect of communication technology on battle area is inappropriate and unnecessary. The triad of shoot, move and communicate are three legs upon which any battle must rest equally. Given this relationship a greater area of coverage by the same amount of forces indicates that the triad is effective and in balance. What is undetermined is whether or not any of the triad is limiting the utility of the other two. Firepower and mobility technology will advance as fast as possible because they are clearly understood and measured. Communication capability either matches (or exceeds) the needs generated by the improvements in the previous two factors or restricts their ability to cover additional area.

Significant Finding: The land area covered by similar forces skyrocketed from World War II to today. During the Saipan invasion a division covered about 40 square kilometers, during Vietnam 350 square kilometers and during Desert Storm 4000 square Kilometers. The synergistic effect of communication, firepower and mobility increases the land area covered by a particular force. Although the differing terrain between island, jungle and desert contributes significantly, overall the effects are more due to technology than terrain or mission. The trend of more land area covered continues as the Commandant's Warfighting Laboratory tests new techniques. During the Hunter Warrior Advanced Warfighting Experiment a Special Purpose Marine Air Ground Task Force operated 150 miles away from their seabase, showing the enlarging ability of technology.

Figure 2

Average Number of Personnel per Square Kilometer

3) Number of users versus the total force:

Definition: This is the total radios that the force used compared to the total number of men in the force.

Discussion: This metric gives a sense of the pervasiveness of force control. It also gives an idea of how small a unit was controlled from a distance. The type of technology and the command structure come together in this metric. For instance smaller unit control would be an indication of fewer maneuver type orders.

Significant Finding: Essentially no change in the number of users that have communication ability

occurred in the last fifty years. There is a small reduction in the number of personnel per radio, most likely due to the shortage of supply in World War II.

Figure 3

Average Number of men per Radio

4) Levels of command with communication capability

Definition: This is an evaluation of how deep into the command structure communication capability, other than visual or manual methods, has reached.

Discussion: This metric is similar to the number of users with the exception that its focus is more on command structure than the amount of coordination conducted. Operation orders lay out which level of the hierarchy has communication by net and level of command. It is impossible to determine specifically the level of usage and the types of orders given, but a general sense of the command communication architecture evolves. Shifting to radio communication greatly improves the mobility of forces, yet the level of command that retained the ability to communicate is the same. In World War II the platoon leader had a hand held radio. Company commanders also used a backpack radio, the SCR-300, that provided longer range communication. Today's communication is still single channel voice on line-of-sight transmission paths. Some major commands retain a few backpack satellite radios for company sized units.

Significant Finding: The depth to which the hierarchy of command maintains radio communication did not change in fifty years. The nature of passing commands did not change nor did the communication architecture. The platoon commander had short range communication ability (less than 25 miles) in World War II and still does today.

Figure 4.

Level of Command With Radio Communication

5) Architecture Conclusion

There is little change to communication architecture at the company and below levels since the beginning of World War II. Nearly all appearances of change can be attributed to the replacement of older methods (messenger, wire) with radios. Today's Marine Ground Component commander uses the same radio net structure used in World War II. The command structure is also the same which may be the driving factor in determining the communication structure.

c) Characteristic Analysis

This section is devoted to the aspects of technology that affect the nature of the communication but are not directly associated with the architecture. Reliability, security, bandwidth use and portability are the key factors covered here. These factors have indirect effects on the communication architecture. While the previous section considered how the architecture changed, this section analyzes the supporting causes of the noted changes.

Characteristics of communication changed significantly in the last fifty years, without causing a change in the employment philosophy. The major finding is that Marine Corps forces are significantly better served by communication equipment. The types of measures considered in the following section deals with the radio net operation rather than structure and distribution.

1) Reliability

Definition: Reliability is used to both define the functional condition of the equipment and also its ability to establish a connection when functioning properly.

Discussion: In a perfect world, doctrine would establish the reliability criteria and then industry would develop a system that satisfies the doctrine. If this were true, a change in the reliability of a piece of equipment would not affect doctrine. In reality, as a technological advance demonstrates its reliability and functionality, military doctrine evolves to include the new capability. The main reason that commercial communication technology is isolated from ground based forces is that the operating environment makes it difficult to maintain sophisticated (usually fragile) communication equipment. Equipment must be able to handle the natural effects of vibration, shock, moisture and dirt. Additionally, equipment must be able to function in spite of enemy jamming, spoofing or assault. The reliability of a backpack radio (SCR-300) greatly affected the conduct of operations in Operation Forager (Saipan):

Little need was found for the messenger dogs, for the SCR-300 radio provided reliable communications for isolated units.

and

"In such a short campaign [FORAGER], however, contact by radio was often sufficient, the infantry finding the SCR-300 a reliable set. ...It was a portable radio set, adopted for carrying on a soldier's back."

Once the radio proved reliable, the commanders eliminated the use of older methods of communication, such as messenger dogs and wire links.

Significant Finding: The doctrinal changes wrought by reliability improvements are not changes to the USMC philosophy of command, but rather changes to the implementation of the philosophy. An argument could be made that the changes are not doctrinal but fall more in the category of tactics, techniques and procedures. What happened is that as equipment proved itself capable, older methods of communication were eliminated. In short, reliability has major impact on the equipment chosen for field

use, but almost no impact on the philosophy of the use.

2) Security

Definition: As used here, security means the ability to prevent an enemy from gaining tactical advantage through the exploitation of communication.

Discussion: Communications are exploited in three major ways: use of the information passed; analysis of the way and the amount of the information passed; and determining the geographic location of the force. The tactical exploitation of the communication usually includes a time factor. If a communication is intercepted and exploited, but the information is not passed to the forces in time it is not a weakness. Analysis that ties certain types of communication to predictable force actions may shorten the time needed to exploit a certain communication intercept. But, in general, most encryption methods and communication techniques provide sufficient delay to void any enemy tactical benefit. So security of communication can be achieved without absolute denial of information to the enemy.

The means to provide information security fall into three categories: encrypting critical messaged components; using equipment that the enemy doesn't possess; and encrypting the entire transmission. Of course the mission commander can opt to not use any form of security at all. During the Somalian relief mission in 1992 little communication security was used initially, however hostile forces did exploit communication so after two to three weeks all transmissions were encrypted. Enemy forces exploited tactical infantry communication as early as World War II. For instance Japanese forces broke the "shackle code" method of encrypting map coordinates during Operation Forager and also imitated valid operators. Perhaps because there was so little impact on friendly forces by this activity the concern for communication security did not arise until late in the Vietnam conflict. Because the exploited information is often not timely enough to be passed to opposition forces it is easy to discount the need for communication security. However, with the advent of more rapid means to both analyze and disseminate communication intercepts, the risk is growing. Each of the major methods of safeguarding tactical information is discussed below.

i) Encrypting critical message parts.

There are many means to accomplish this, including some of the most secure means. Single use pads of codes are nearly impossible to break because there is no pattern to analyze. This method requires the radio operator to encrypt the critical plain language portions of the message. This added encryption step makes this method the least popular, particularly among tactical forces. However simple methods of protecting information are often used. During operations in Croatia, Canadian UN forces were taken under fire when hostile forces exploited unsecured Canadian shell reports. The hostile forces used the shell reports to correct their targeting of UN forces. The UN had decided inappropriately that no communication security was necessary. A system of modifying the map grid coordinates allowed later shell reports to be made without providing hostile forces a method of correcting targeting errors.

ii) Equipment not Held by the Opposition.

Relying on the inability of the enemy to understand a transmission because we have a new method of transmitting is the most arrogant and risky method of communication security. One captured radio or the technical analysis of an intercept can often negate the value of relying on technology for security. For instance the AN/PRC-77 used a method of spreading transmission over a large spectrum to provide an added measure of security. Although there is no recorded compromise of this method, the addition of encryption devices indicated a concern that spread spectrum transmission did not provide adequate security. New methods of transmission can provide much in the way of readability and range but should not be relied upon to secure a communication channel.

New equipment can provide the means to greatly reduce the vulnerability of forces to having their geographic location determined by hostile forces. A variety of new technical approaches to communication are much less susceptible to interception, basically using the physical characteristics of the transmission to make intercept impossible. Control of the electronic emissions is the primary means of protecting location information, but new methods of transmissions can protect the forces from many methods of position determination.

iii) On Line Encryption.

This method encrypts the entire transmission by using a device between the transmitter and receiver to secure the communication. This method requires no operator action to use, other than the initial setting of the encryption device. The setting of the encryption device was simplified recently by the addition of a resetting device that automatically receives encryption from a master station. The benefit of on-line encryption is ease of use; today's on-line encryption devices provide security without detriment to the user.

The difficulty with on line encryption is that the receiving station must be set up in a compatible format or no communication occurs. This is true also for unsecured communication but secure communication is much more likely to have problems since there are many more possibilities for incompatible settings. Another problem with encrypted transmission is that if there is a problem, the natural response is to go unsecured and conduct the transmissions in a vulnerable mode.

Existing methods of commercial encryption technology can provide interoperable, secure communication with coalition forces. The latest devices allow several kinds of encryption methods for different levels of security. For instance, a commercial Digital Encryption Standard (DES) cellular phone could provide interoperable tactical security with many nations. The DES standard is both exportable and widely used. The key benefit is that although the standard is not as robust as military encryption, the time it would take an adversary to decrypt an encoded digital signal would make the intelligence gathered untimely to the enemy, thus protecting our forces.

A side benefit of using commercial technology is that commercial channels can be used. Because many

businesses encrypt their transmissions to protect proprietary information, military use of the same codes would make military transmissions indistinguishable from commercial traffic. This would deny the hostile forces both the information and the ability to analyze the way the traffic is being sent.

Significant Finding: Security of communication transmissions is crucial to forces operating across the spectrum of conflict. However, encrypting the transmissions did not change the nature of military command.

3) Data Rate / Bandwidth

Definition: Data rate is a measure of the amount of information passed in a specified unit of time, usually a second. Bandwidth is a measure of the amount of the frequency spectrum. For example a radio with a 30 kilohertz bandwidth could be assigned 300,000 to 330,000 Hertz. Any radio on the same net would be assigned the same range of frequency. Bandwidth is closely related to data rate, however radios use bandwidth differently so it is not always directly related.

Discussion: Data rate and bandwidth are probably the most misunderstood and misused terms associated with information transfer. Statistical analysis of data rate provided to a force or to an area of interest is nearly useless for any practical analysis of communication. The data rate provided to USMC forces increased substantially between World War II and today. At many levels of command the increase is tremendous. The benefit of increased data rate is another matter. A division commander with a single voice channel to higher headquarters has about three thousand bits per second of data rate. Give that same commander a video teleconferencing channel and he has one million bits per second of data rate. So the commander now has a three hundred fold increase in bandwidth. The acquisition minded warfighter would say that the warfighter can use this ratio as a force multiplier and reduce the fighting strength of the commander to one three hundredth of the initial force. While seeing the face of the reporting senior transmitting an order is useful, a verbal order takes as long to transmit over a low data rate voice only circuit as over a high data rate video circuit. Additionally, the voice circuit may be all that is necessary to communicate an effective order. Conversely, take the data capacity of the video circuit and turn it into three hundred voice telephone lines and the coordination gained can be a force multiplier. When forced to make a choice, the increase in coordination ability is most likely the more efficient use of the additional data rate. Voice-only command circuits are proven by fifty years of use and refinement. The low data rate data channels have their purposes as do the video channels. Low data rate channels can provide low priority requests such as the transmission of photographs, map and operation orders. In some cases the video channel is crucial to the higher command authority and must be kept as a capability, especially in this era when the visual presentation of a situation has as much impact as the commander's assessment.

There is a major problem facing the military communicator when dealing with bandwidth. The frequency spectrum is a highly sought after commodity in this information age. Congress has increasingly cut portions out of the military allocation to allow the proliferation of personal communication devices and other civilian wireless information transfer equipment. In the international arena the loss of spectrum is

becoming critical; the military communication planner has to take into account the effects of military communication on the host nation telecommunication network. Often the military communication equipment uses the same frequency as the local cellular network. The end result is that for many operations the military needs a system that can quickly reconfigure to host nation and situation requirements.

In addition to providing clearer, reliable communication, digital technology also contains the capability to more efficiently use allocated frequency bandwidth. Most communication equipment uses the same amount of frequency bandwidth that it did fifty years ago. In other words, even though existing circuits provide clearer, secure communication, it uses the existing frequency spectrum inefficiently. Nearly all existing communication equipment must be assigned a particular band of frequency that remains dedicated to the equipment even when not in use. Even a digital system can have this limitation unless it is designed to allow other transmitters to share the bandwidth.

Consider the typical voice net. There may be thirty users on the net, but in most cases only two can use the net at a time. Furthermore, in order for human communication to be understandable there must be spaces of silence. Properly designed digital equipment can allow the silences in one conversation to pass information from another conversation. During the 1995 Joint Warrior Interoperablity Demonstration (JWID) conducted by the Joint Staff Military Communication Electronics Board, a net between the USS Nimitz, USS Cowpens and the San Diego Naval Communications Telecommunication Master Station measured a five fold increase in data rate over a fixed bandwidth. The same net allowed large messages to travel over multiple nets, cutting the time of transmission by seven fold. An additional benefit, observed when the USS Cowpens lost its satellite link, was that the system automatically routed messages over alternate paths--without operator interaction. A system that can handle resource allocation allows the commander to rapidly shift communication assets between video communication and voice circuits as required by the tactical situation.

The problems faced by today's military communicator are not new; indeed many historical references to congestion on critical circuits exist. During Operation Forager in World War II this complaint was lodged:

The SCR-536, a small hand carried radio was also used on Tinian by platoon leaders and company commanders. The range of these however, did not exceed a mile or so; the waterproofing was inadequate for the almost daily rain; and transmission was often blanketed by other stations on the net.

Significant Finding: The control of allocated bandwidth and data rate is crucial to operations. World wide commercial use of the frequency spectrum is crowding the spectrum available for military use. Any future military communication architecture must account for the reduced spectrum and the need to reduce the impact on the commercial sector. The military systems in use can be modified along the lines of JWID experiments, resulting in a robust system that provides the necessary data rate to support warfighter needs.

4) Personnel and Weight

i) Dedicated Communicators

The communication community receives criticism about each new communication system being too hard for general use and therefore requiring specially trained personnel. By using commercial technology, making the encryption transparent to the operator, and automating the routing of messages, training and dedicated communication personnel can be reduced. Digital communication techniques allow the system itself the ability to route traffic, find alternate routes and handle priority with less operator intervention.

Trained communication operators will always be necessary to establish command posts, key nodes and ground communications. Wide use of commercial equipment will reduce the need for special operator training. New recruits will arrive with a basic knowledge of computers and cellular telephones. Commercial telecommunication companies have a world wide focus and several established world wide communication satellite networks available for use. The military is a small communication user and therefore, by using compatible technology, can capitalize on the fact that a large market drives a lower per unit cost. The added benefit is that the planned growth room built into the oncoming systems will provide more capacity for contingency operations.

Significant Finding: Commercial, digital equipment reduces operator intervention, allowing better use of communication personnel.

ii) Mobility

With the advent of pervasive commercial media, particularly television, the tactical actions of a single Marine can have strategic implications. This fact of life, more than many other factors, drives the need for a commander to have direct access to all members of the command. Using the miniaturized components and improved signal strength of commercial technology, the amount of equipment necessary to provide tactical communication is greatly reduced. The implication is that instead of only company commanders and above having operational level communication, that capability can be extended to all levels of command if necessary. Additionally, higher levels of command can link into one of the global satellite carriers and forego the larger military satellite dishes.

Two major commercial systems, International Maritime Satellite (INMARSAT) and IRIDIUM plan global cellular communications with a hand held unit by 1999. IRIDIUM is a network of Low Earth orbiting satellites, in the process of establishment, but will provide a hand-held cellular type phone the capability of world wide connectivity. Additionally, the IRIDIUM unit will have a dual mode capability that allows the unit to use either a terrestrial circuit or satellite net without operator action. One concept of military operation would be to tie into a global satellite system with an encrypted cellular type phone. For more local operations, an Unmanned Airborne Vehicle (UAV) could carry a repeater to provide the necessary communication connections. In either case, no vulnerable ground stations are located in country. As the force footprint increases, the large military satellites can be brought in to meet the robust,

back up communication requirements.

Significant Finding: Commercial digital equipment provides mobile, world wide connections for all levels of a command structure.

iii) Size and Weight

The commercial equipment often comes in a variant used to target the emergency services commercial market. Many of these units could survive the environment that a Marine faces in the field or could be modified cheaper than procuring a device built to military specifications. There would need to be logistics considerations to provide recharging stations, replacement units and servicing. These considerations are offset by the light weight and low power requirements. Many of the commercial satellite stations are even solar powered. Solar power can provide an additional method of powering military communication with less infrastructure. For instance, long term reconnaissance teams could use a solar powered unit to maintain communications without needing a noisy generator.

Significant Finding: Much commercial equipment is designed for individual users, who desire small, low weight units. This market fact drives commercial providers to create units ideally suited for a military user.

5) Characteristics Conclusion

The major changes in the last fifty years did not support a change in the communication structure, particularly at the lower levels of command. The widespread use of encryption and satellite technology allows longer range, secure communication, but no change to the net structures. The emergence of digital technology provides a change in the basic principle of communication. Digital not only provides a clearer signal, it add a measure of intelligence to the network, previously provided by operators. Now a transmission can be routed to its destination automatically. For instance the existing Position Location Reporting System capability for short position type information coupled with a commercial, digital cellular system would allow the entire chain of command the ability to contact a specific element without having to contend with a multiple user netted voice circuit. As digital communication methods prove reliable, commanders will use them. The key benefits of digital communication need to be exploited not only as replacement for existing equipment but also for their unique capability to provide better net control.

By shifting our focus to commercial, digital communication, the military communication architecture can take advantage of the commercial sector advances. With digital capability the communication architecture changes within milliseconds. Also, by expanding the level of forces that have digital interoperability, the level of the force that can have strategic connectivity could be at the fireteam level. Additionally, digital devices can be automatically configured for interoperable communication if necessary--greatly reducing the coalition force coordination effort.

Another advantage of the revolution and proliferation of information technology is that industry is facing and answering the challenges of living with a congested frequency spectrum. Commercial technology has the capability to handle the problems noted. Had the SCR-536 been one of the rugged digital cellular phones used by civilian emergency personnel today none of the congestion or range problems would have been experienced.

The fundamental nature of human communication is reflected in that command nets remained voice circuits. The extra level of certainty and understanding that a voice connection provides is both human nature and situation driven. Humans naturally communicate best face-to-face. A trade off consideration between data rate and utility is necessary. When should a video circuit be transformed into 300 voice circuits or 3000 text circuits? The interaction that a voice connection provides reduces misunderstanding. Voice is often faster than text communication because it cuts out the drafting and delivery cycles that are often difficult or impractical to implement. Although video communication may someday be the medium of choice for lower levels of a command, trade offs of technology drive the focus of effort toward voice and text communication.

The characteristics of military communication only recently turned toward digital communication and then only in exercises or major command centers. The fifty years of improvements to analog communication are inherent with digital and with added benefits. The strictly analog radio should go the way of the phonograph record. Only digital communication supplements military communications enough to meet the electromagnetic challenges of the next century.

CHAPTER 3

SUMMARY OF FINDINGS

The communication technology developed over the last fifty years failed to provide a reason to change the structure of military ground force communication architecture, particularly at the lower levels of command. Significant advances in the reliability and range of equipment came forth, but nothing sufficient to support a true revolution in the way communication is handled. There is a capability that is not being used that will provide a revolution--digital communication is used but not digital controlled communication nets.

Digital communication as presently used is essentially the same as older methods with the exception that since a digital signal must be only one of two values all other values (noise) can be rejected. Rejection of noise is especially useful when relaying the signal. However, even the latest system, the Single Channel Ground and Airborne System (SINCGARS), is essentially a digital variation on the older radio schemes. Sincgars comes with a variety of features that improve greatly on the older radios, but it provides only single channel, primarily voice circuits.

The next step forward is to use digital or computer control of the communication. The disadvantage is that controlling a large, global network requires an investment in communication that the Naval

Department is probably unable to make. Although there are inherent problems with using commercial systems, particularly ones that have potential adversaries as partners, the infrastructure to provide digital controlled communication is in place. What remains in the analysis is the trade off between commercial systems and military systems. Without going into a lengthy technical discussion about advantages and disadvantages of different technical solutions, consider that the designers and operators of the system stand to lose billions of dollars if there is a vulnerability in the system. Additionally, the consortiums creating the different nets are in competition to provide better service than their rivals. The international consortiums also have more research and development funds and are unhampered by the bureaucratic tangle experienced by government agencies. The final conclusion must be to use a mix of existing military and commercial systems to provide the necessary communication for the expected conflicts of the future. Neither military nor commercial alone can meet all the needs of the warfighter.

CHAPTER 4

RECOMMENDATIONS

Changes in communication architecture are needed to support Operational Maneuver from the Sea (OMFTS), non-traditional battles, and Military Operations Other Than War (MOOTW). In Somalia, military relief teams often traveled without communication because of the lack of secure, portable satellite terminals. Many of the proposed battle and operation scenarios include small teams operating outside of the communication coverage of standard equipment. Portable military satellite terminals are in short supply and also the capacity of the satellites is limited. To cover the entire range of operations proposed by the current doctrine, a mix of military and commercial communication is necessary.

To be a viable participant in future expeditionary operations the Marine Corps must have the ability to communicate with non-governmental organizations, allied nations and coalition partners. None of these non-governmental organizations will likely procure military hardware to meet their communication needs and the military does not have the funding to provide the necessary communication equipment to them. Further complicating matters, the United States' secure military equipment is not releasable to most organizations involved in a relief effort. By using commercial, ruggedized equipment, with commercial encryption devices, the goal of secure reliable communications is met. Commercial encryption eliminates the tactical utility of intercepted transmissions while ensuring the safety of the force using it.

a) System Characteristics

To meet the needs of the expected situation the commercial system or systems need to provide the following:

1) Global coverage.

2) Small, cheap units, preferably handheld.

3) Secure communication ability. Encrypted transmissions, with a wide range of compatibility, to include commercial, coalition and US military standards. This should include methods of protecting against radio theft such as voice identification.

4) Automatic switching of calls. This includes intelligent selection of a path that can bypass a failed or busy link.

5) Station elimination. The ability to remotely disable a compromised radio.

6) Station grouping. The ability to select a group or radios to receive a particular transmission.

7) Bandwidth use optimization. The ability to assign bandwidth as necessary to support the tactical need of the operation. This includes the ability to trade high bandwidth video circuits for multiple voice or data circuits.

8) Routine report capability. The ability to send a short data at each transmission that updates commonly reported data such as position and unit identification.

9) Interoperability. Compatibility with multiple commercial cellular and satellite systems, to include a software update capacity to incorporate new standards.

10) Back-up capability to handle peak traffic periods.

b) Architecture Vision

Communication is vital to all levels of command, however higher levels of command have advanced communication capability while the lower levels use equipment not much different than that of fifty years ago. With the explosion of commercial information transfer ability the means to provide the lower levels of command the necessary communication is possible and affordable. The final architecture should encompass a mix of commercial and military hardware. Existing equipment is critical to provide backup and overflow capacity. New equipment should be procured to meet the ten system requirements proposed above.

The opposing view to using commercial technology is that it is not as protected as the military system. Careful analysis of the vulnerabilities of the capability of the in theater adversary and the likelihood of their desire to eliminate commercial communication needs to be added to communication planning. Where it is not vulnerable, commercial communication should be used. Military hardware provides the backup necessary for major military operations and for adversaries that will target commercial communication.

New procurement options are opening up daily. The IRIDIUM satellite cellular phone system is one of the most promising capabilities on the horizon. IRIDIUM has the satellite-borne capacity to route calls

with cross satellite links and a hand-held unit that possesses the ability to connect to a local cellular system. The fielded hand-held units have a data transmission ability that could be used to send Global Positioning System derived location data along with a unit identification that would reduce the verbal communication. Because the signal is digital it is inherently harder to exploit, but adding an encryption module to the hand held unit would add a measure of security to the call. IRIDIUM has the added advantage in that it uses Low Earth Orbit (LEO) satellites that require less power to use and also provides coverage over the polar regions (60 degrees latitude to the pole) of the Earth. IRIDIUM may not be the final choice, but its system capability can mix a battle field cellular system with satellite communication for longer range requirements without requiring special operators and an expensive military communication facility. The command post has an additional advantage with a global cellular system in that the phone numbers do not change with location. This allows standardization of the communication plan and also the ability to practice with the communication assets (literally, as a LEO satellite's path covers the Earth during a fairly short period of time) that will be present at the deployment site.

The existing military equipment can be used for the local (less than 25 miles) coordination efforts and also to keep a backup capability as insurance against a failure of the commercial system. The existing military equipment can also be used, with augmentation, to provide the battlefield presentations at the major command posts. Commercial equipment should be phased into use, starting with the levels of command that are lacking communication capability, yet are often those called upon to perform missions in remote regions without adequate communication ability.

As was learned in World War II, a lesson can be garnered from the law enforcement and fire departments. In Fairfax County, Virginia, the Public Safety Communications Center already uses a digital system to dispatch personnel to problem areas. A police officer can conduct an entire patrol without voice communication. Voice communication is reserved to what it should be used for, the passing of crucial information rather than routine reports. Planned upgrades include continuous automatic position reporting and a trunked, encryption-capable digital voice system. Some police departments use a thumb print scanner to verify a suspect's identity. Helicopters and many patrol units also have a live video feed back to supervisory personnel. For small units operating in Low Intensity Conflicts (LIC) or humanitarian operations, practices used by police departments provide an outstanding example of efficient and effective use of commercial technology.

The final component of the architecture is to include the processing ability in the command center to handle all the position reports. A straight forward method of using all the position information would be to group the positions by organization and place a symbol at an appropriate position, such as the command post or the geographic center of the dispersed components.

CHAPTER 5

Conclusion

The existing communication system provides the robust communication necessary for a traditional

battlefield. Although technology advances of the last fifty years impacted the quality of battlefield communication, no significant change in the structure or employment of communication networks occurred. The lack of change is indicative of a practical sense of function rather than a lack of initiative. No technology other than the change to digital technology has the ability to replace operator functions. The control of communication is the critical area for advancement , however, until now the technological ability did not exist.

All prior communication methods used by the infantry units functioned on the net principle, that is, a common frequency with multiple stations. The net limitation is that a commander can not monitor all nets without having a dedicated radio for each net. Using digital methods the limitation for a dedicated radio is lifted. With digital control the commander, with one radio, can page a particular unit or specify a group of units to receive a broadcast. Automatic functions can report position and acknowledge communications. The flexibility of a digital system is a key strength particularly for forces required to be ready for multiple missions.

Although there is experimentation with new tactics, World War II amphibious tactics are effective and still a part of doctrine, primarily because of their demonstrated effectiveness over a variety of situations. The similar experience and capability of existing communication should not be discarded but rather used as the gold standard against which new capability is measured. Digital-controlled, commercial technology can provide the means to support the new concepts of maneuver warfare, but only if applied thoughtfully with a clear vision of the vulnerabilities and the best way to implement the strengths.

Communication nets saw little change in the last fifty years because technology could not support different procedures. Now that the military's job is changing from major assaults concentrated in a small area to small units operating independently, the need to communicate to these units is a critical vulnerability. Commercial technology provides an affordable addition to the existing military network that supports small unit operation, without destroying the capability to conduct a large scale operation.

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