Chapter 1

Introduction

1-1. Army Space Activities

a. Tactical satellite (TACSAT) communications is part of a larger group of Army space activities. The Chief of Staff, US Army (CSA) directs all Army space activities through the Vice Chief of Staff, US Army (VCSA). The VCSA is chairman of the Army space council. This group recommends and guides the CSA in Army space-related activities such as current and future space missions and the Army's mission in the unified United States Space Command (USSPACECOM). The Army space council is made up of representatives from selected Army staff agencies, field operating agencies, and major commands. A general officer from the United States Army Information Systems Command (USAISC) is a member of the Army space council.

b. The Army Space Institute (ASI) and the United States Army Space Command (USARSPACE) are the two Army organizations for space. The ASI is a field operating agency of the United States Army Training and Doctrine Command (TIWIOC). Missions include developing and integrating space-related concepts and doctrine across mission areas. USARSPACE is under the operational command of the USSPACECOM and will expand the Army's role in the operational aspects of space. USARSPACE missions include operating the Regional Space Support Centers (RSSCS). These centers provide the ground mobile forces (GMF) manager support for the super high frequency (SHF) TACSAT segment and GMF control.

1-2. Military Requirements

a. Command, control, and communications (C^3) is the key to success in the AirLand Battle. Due to technological advances, greater mobility, and the extended battlefield, radio communications is paramount in the communications plan. However, while technology has improved the equipment, communications has not kept pace. Two limitations are the congested frequency spectrum and the physical limits on radio wave propagation. The frequency required for long-range radio adds to the frequency congestion problem. Requirements normally exceed the available, useable frequencies. Frequency congestion and inherent limitations of terrain and noise hamper short-range tactical radio.

Coupled with the need for flexibility, security, and reliability, radio communications remains a critical problem to the communicator.

b. TACSAT communications is the first radio system to successfully overcome most of these limitations. Using an orbiting satellite repeater illuminates one-third of the earth for direct line of sight (LOS) operations. This makes it possible to establish tactical communications on a scale never before accomplished. With more frequencies available and a single station LOS relay to almost any point on the battlefield, TACSAT equipment greatly enhances communications.

c. TACSAT communications is reliable, flexible, and survivable. It can replace certain links previously provided by conventional LOS radio relay, troposcatter, high frequency (HF) single sideband (SSB) or frequency modulated (FM) radios. The tremendous bandwidth available and computer switching makes a self-organizing communications network feasible. TACSAT communications is not the answer to all communications problems. However, a well thought-out, properly executed plan that augments the traditional ground-based communications system with appropriate TACSAT resources can improve communications availability, reliability, and flexibility.

1-3. TACSAT Systems

a. TACSAT systems, like terrestrial systems, vary depending on the communications requirements. Just as there is a need for both HF SSB and very high frequency (VHF) FM radio in the tactical environment, there is also a need for different satellite systems. The peculiarities of mission requirements make it necessary to have different TACSAT communications systems.

b The TACSAT communications systems of the US Army ground forces operate in one of four categories.

(1) The Army Multichannel Satellite Communications System’s terrestrial terminals are the AN/TSC-85( ) and 93( ). The Air Force terminals are the AN/TSC-94A and the AN/TSC-100A. The satellites used for interconnectivity of these multichannel terminals are Defense Satellite Communications System (DSCS) IIs and DSCS IIIs. The frequency range of this system is SHF (7.9-8.4 GHz for uplink and 7.25-7.75 GHz for downlink.)

(2) The Special Communications System (SCS) is controlled and managed by the ultra high frequency (UHF) Air Force Satellite Communications System. The US Army ground terminals used in SCS are AN/MSC-64(V) and AN/GSC-40(V). The frequency range of the system is UHF (225-400 MHz) for up and downlink communications.

(3) Authorized Army units use the AN/PSC-3, AN/VSC-7, AN/URC-101, and AN/URC-110 for extended range communications. The frequency range of the system is UHF (225-400 MHz) for up and downlink communications.

(4) When fielded, the AN/TSC-124 (known as, single-channel objective tactical terminal (SCOTT)) will provide ground terminals for special communications system and joint theater command communications. The AN/TSC-124 groups users into nets with common cryptographic keys and addresses. It allows a telephone type "dial up" of another net member, mainly in a data mode. The frequency range of this system is extremely high frequency (EHF) (uplink) and SHF (downlink).

1-4. Transmission Techniques

a. To use TACSAT communications effectively, it is necessary to be familiar with the terminology and techniques that are used. It is not practical to have a separate satellite for each radio net or link. The satellite system must make provisions to relay signals of many nets at the same time. This is called multiple access. There are two basic types of multiple access--frequency division multiple access (FDMA) and time division multiple access (TDMA).

(1) FDMA is the first technique used for satellite multiple access because it uses existing frequency division technology and equipment. It is simple to implement, has proven performance and reliability, and is easy to maintain. Using FDMA, each terminal accessing the satellite transmits on a different frequency to the satellite. The satellite receives and retransmits the signals over a broad bandwidth encompassing the frequency range of the ground stations. The satellite electronics package is usually referred to as a transponder. The satellite translates the frequencies and retransmits them with the same relative frequency relationship back to the ground nets. This translation avoids interference between the satellite's input and output signals.

(a) Ground radios in an FDMA satellite net must transmit and receive on separate frequencies. These frequencies are spaced equal to the satellite frequency translation. This prevents direct radio contact between radios operating in the same net. Although this method is simple and reliable, it has drawbacks. Each single-channel net or one-way link requires two radio frequencies. A duplex link through the satellite requires four frequencies. Also, for direct linkage between two ground stations, without going through the satellite, frequency switching of the ground radio transmitter to the satellite transmit frequency is necessary. This complicates operational control and introduces the potential for interference due to operator error.

(b) With many nets operating at the same time, signals can be mixed due to different signal strengths arriving at the satellite. This is called intermodulation. It generates signals which can cause interference and noise. These mixing products also reduce the useable power output of the satellite. Satellite transmit power output must be divided among all the users in an FDMA system. Any power used in mixing and on noise reduces the power available for communications. Also, any unequal distribution of power among the users can impact on the successful operation of the FDMA satellite. Careful frequency selection and control of ground station transmit power is necessary to make an FDMA system work properly. Usually a centralized ground monitor and control point is essential. Despite these limitations, FDMA is an effective tactical system because of its simplicity. It foregoes the need for sophisticated timing necessary in TDMA systems.

(2) TDMA assigns a specific time interval for each ground terminal or net to use the satellite. This eliminates the FDMA need for frequency and power control of each ground station accessing the satellite. TDMA removes the potential for intermodulation caused by nets operating through the satellite at the same time. With each net having its own time to use the satellite, each net can use the maximum ‘power and bandwidth of the satellite. However, to make the system work, rapid switching between nets is necessary to eliminate delays in net communications. This reduces the transmission time available to each net. It requires careful timing at each ground station.

(a) An alternative to accurate timing is slow switching among many nets or stations. Slow switching causes a delay in communications but is overcome by a priority break-in feature. For example, by giving each ground station satellite access for 4.5 seconds once every 5 minutes, 50 stations could be accommodated. A 0.5 second time slot is available each 5 seconds for emergency break messages. This technique is most attractive with narrative record communications operating in a store and forward mode. The break-in feature is also useful for some special communications requirements.

(b) Regardless of the switching speed, digital transmission is almost an absolute necessity. The switching of time slots is digital; therefore, the communications must match. This means all signals transmitted in the TDMA system must be digital for transmission. Analog signals must be converted before transmission and reconverted after reception. However, using digital transmission and reception makes TDMA more attractive because of the compatibility with electronic switching systems and cryptographic equipment. TDMA communications is in short intermittent bursts; therefore, the ground stations must store or buffer information allowing continuous input and output of traffic.

b. With multiple access, the number of channels on a satellite is limited. If each channel through the satellite is dedicated to a specific net or user, the number of users can quickly exceed the available channels. If a given channel is not being fully used by a net, a valuable satellite channel is partially wasted. This is not efficient and leads to delays and limited channel availability. FDMA and TDMA do not allow for efficient use of the available satellite resources.

(1) Demand assigned multiple access (DAMA) is a technique which matches user demands to available satellite time. Satellite channels are grouped together as a bulk asset, and DAMA assigns users variable time slots that match the users information transmission requirements. The user notices no difference--to him it seems he has exclusive use of the channel. The increase in nets or users available by using DAMA depends on the type of users. DAMA is most effective where there are many users operating at low to moderate duty cycles. This describes many tactical nets; therefore, DAMA is particularly effective with TACSAT systems.

(2) DAMA efficiency also depends on how the system is formatted. Formatting a DAMA system is how the access is controlled. The greatest user increase is obtained through unlimited access. This format sets up channel use on a first-come-first-serve basis. Other types of formats are prioritized cueing access and minimum percentage access. The prioritization technique is suitable for command type nets, while the minimum percentage is suitable for support/logistic nets. Regardless of format, DAMA generally increases satellite capability by 4 to 20 times over normal dedicated channel operation.

c. Spread spectrum multiple access (SSMA) is a technique which uses a wideband signal to convey intelligence through the satellite. This signal may be many hundreds of megahertz wide. The advantage of a signal spread over a great bandwidth is that power density (watts per hertz) is lowered by the same amount that the spectrum is widened. This interchange of power for spectrum space can reach a point where signals can be transmitted and received while hidden below the background noise. Such low density signals can reduce the problem of interception and at the same time prevent interference to other satellite users. Spread spectrum systems allow many users to share a single wideband channel. Information to be transmitted by spread spectrum is first converted into digital form to provide a primary modulation of the carrier. A secondary pseudorandom noise modulation of much wider bandwidth is then applied to the carrier to spread the spectrum of the primary modulation. At the receiving end, an identical noise generator, synchronized to the transmitter, generates the same noise code to cancel it from the incoming signal. Thus, only the transmitted information remains. This spread spectrum technique is called direct sequence (DS). The basic form of DS is produced by a simple, phase shift keying (PSK) carrier frequency. In the DS spread spectrum signal, the modulated signal appears instantly across the total bandwidth.

(1) The advantages of DS spread spectrum processing are--

- Signals are difficult to detect.
- Maximum transmitted power for the bandwidth used.
- Interference and jamming protection.
- Reduced noise.
- Discrete address.
- Multiple access.

(2) Another form of spread spectrum is frequency hopping (FH). FH uses a pseudorandom code generator to switch the carrier frequencies producing a hopping DS spread spectrum. Frequency hoppers can use hundreds to thousands of frequencies.

d. In spread spectrum systems and TDMA, timing is a necessary process. Transmitter-to-receiver phase and frequency timing requires resolution before a spread spectrum or TDMA receiver can operate. These problems are overcome by transmitting timing signals at the start of each transmission. A system clock produces a timing preamble code for timing of the network. The preamble of a transmission from any terminal carries timing information for the receiving terminal. System or network control assigns the terminal transmitted time slot. This carries timing in the preamble and discrete address(es) in the data segment. Each receiver uses the transmitted preamble for fine adjustments.

e. Addressing a message designated for a specific terminal is similar to a telephone call. When dialing a telephone number, the electronic switching equipment directs the telephone system circuits to connect the caller and addressee. Basically, the telephone system has a “discrete call” capability. A discrete call capability is required in multiple access transmission systems. The form of discrete call needed in a TDMA communications system is transmitter to receiver recognition, not subscriber to subscriber. Although all receivers will fine-tune to the timing signal, only the receiver recognizing its address in the code will copy the text.

1-5. Planning and Control

a. Tactical communications networks change constantly. Unless control of the network is exercised, communications delay and a poor grade of service will result. The best method of providing this control without hampering operation is through centralized planning. Execution of these plans should be decentralized. This concept is applied to the space systems portion and to the ground stations. The US military satellite systems consist of terminals (ground segment), satellites (space segment), and tracking, telemetry, and control (TT&C) terminals (control segment).

b. The planning and system control process helps communications systems managers react appropriately to the mission of the force supported, the needs of the commander, and the current tactical situation. The type, size, and complexity of the system being operated establishes the method of control.

(1) Communications control is a process in which the matching of resources with requirements takes place. This process occurs at all levels of the control and management structure. In each case, the availability of resources is considered.

(2) Operating systems control is the detailed hourly management of a portion of a theater Army, Army group, corps, or division communications system. Planning and control is according to the system being used.

c. The Defense Communications Agency (DCA) provides technical guidance on satellite control in support of the Joint Chiefs of Staff (JCS). Course allocation of satellite payload communications resources is done by DCA based on JCS directives. The Army, Air Force, and Navy have operational responsibilities for satellites and satellite payloads. These responsibilities involve using several sites worldwide to provide planning and control for a communications satellite constellation.

d. Satellite control is split into two categories: TT&C and payload control. Because there may be hundreds of users on a communications satellite, payload control is often subdivided among major user groups. In DSCS, a portion of the payload bandwidth and power is used to support the GMF terminals. GMF managers and controllers handle the planning and control. The overall DSCS controller monitors the GMF portion of the satellite system either as a subnet or as individual carriers. However, this monitoring depends on the availability of satellite resources. Chapters describing the specific system cover the user’s interface with satellite planning and control.

1-6. Space Segment Descriptions

a. The satellite system operating in the UHF band is the Fleet Satellite (FLTSAT) System. FLTSAT is presently providing worldwide support to all services and agencies between the latitudes of 70 degrees north and 70 degrees south. However, the Navy primarily uses this system. Each FLTSAT can relay communications on 23 separate radio frequency (RF) channels. There is one fleet broadcast 25 kHz channel and SHF beacon; nine fleet-relay, 25 kHz channels; 12 Air Force satellite communications (AFSATCOM) narrowband 5 kHz channels; and one AFSATCOM wideband 500 kHz channel. FDMA allows access to the 500 kHz transponder by seven high data rate (2.4 kbps) users and 13 low data rate (75 bps) users. Army users may request using the nine fleet-relay channels, the five nonprocessed 5 kHz channels, and limited access to the wideband transponder. However, there are currently no satellite transponders dedicated to Army use. Army users must send an access request directly to the Air Force or Navy. Access is based on the established prioritization schedule published in JCS MOP 178. The Office of JCS has formed the Joint Communications Satellite Center (JCSC) to act as the controlling agency for satellite access. Network control and spectrum availability are the responsibility of the Air Force and Navy. All non-Navy users must direct their frequency requests through their local frequency management office to the Navy's frequency management office. The overall FLTSAT system has more than 600 user terminals on board ships, aircraft, and on shore. The FLTSAT space segment consists of four satellites in synchronous orbit. The satellite transponders operate in US military UHF bands.

b. The multichannel TACSAT terminals use the spacecraft transponders of the DSCS. The terminals use both DSCS II and DSCS III satellites. The DSCS II satellite has two transponders, each providing two operational channels. These transponders are cross-linked to provide four operational channels to the earth coverage (EC) and narrow coverage (NC) antennas. Each NC antenna can transmit and receive simultaneously. (DCAC 800-70-1 covers on-board antenna interconnectivity of the DSCS II channel.) The signal transmitted by the ground terminal is received at the satellite in the 7.9 to 8.4 GHz frequency range where it is down converted, amplified, and retransmitted in the 7.25 to 7.75 GHz frequency range. The two NC antennas can be independently steered ±10 degrees, and the footprint--the part of the earth covered by the antenna-- covers an area about 1,200 kilometers (750 miles) in diameter. The newer DSCS II satellites have one of the NC antennas adjusted to provide a 2,400 kilometer-wide (1,500 mile-wide) coverage area, known as area coverage (AC). The EC antennas (transmit and receive horns) provide coverage to about one-third of the earth's surface.

c. The DSCS III satellite has six independent transponders (one per channel), three uplink antennas to receive signals from earth terminals, and five downlink antennas which retransmit the signals back to earth. The signal transmitted by the ground terminal is received at the satellite in the 7.9 to 8.4 GHz frequency range where it is amplified, down converted, and retransmitted in the 7.25 to 7.75 GHz frequency range. The DSCS III will replace the DSCS II satellites over a period of time. At this time, both are in orbit. The DSCS IIIs have some improvements over the DSCS IIs such as increased hardening, a nulling capability (antijam function), and more transponders. However, the DSCS III only has one NC gimballed dish antenna (GDA). This limits the number of locations that can be covered at any one time. The DCA can change footprint locations. (DCAC 800-70-1 covers on-board antenna interconnectivity of the DSCS III satellite channel.)

1-7. Electronic Warfare

TACSAT communications is an important element of the battlefield command and control system. Part of the enemy's resources are directed against the satellite system through electronic warfare (EW). How vulnerable we are to enemy EW and the success of our actions to deny the enemy success in his EW effort depends on our equipment and our signal personnel. While there are many components of EW, this manual deals only with TACSAT communications systems. The first two EW components, electronic warfare support measures (ESM) and electronic countermeasures (ECM), are technical. We rely on military intelligence (MI) units and the United States Army Intelligence and Security Command (INSCOM) for advice and implementation of ESM and ECM. Radio electronic combat (REC) is the enemy equivalent to our ESM and ECM. To counter enemy use of REC, the Army relies on communicators to use electronic counter-countermeasures (ECCM).

a. Electronic threat. The enemy uses REC measures to collect intelligence data about our signal systems. The enemy then decides what REC would be appropriate from the data gained through intercept. TACSAT communications will be high on the enemy REC target list. Shortly after tactical communications is placed in operation, the enemy will compile data on the satellite. This data will most likely include--

- Data indicating the satellite's orbit and location.
- Information on frequency, bandwidth, and modulation used in the satellite.
- The amount, type, and frequency of traffic relayed by the satellite.

With the satellite relay located, the primary enemy REC threat then is directed toward locating ground stations through radio direction finding (RDF). Due to the highly directional antennas used with SHF/EHF TACSAT communications radios, there is a low probability of intercept and direction finding. But, a satellite-based intercept station orbiting near our satellites can be successful. In this case, the analysis effort can be done by the enemy on his home ground, far from the battlefield. Because of the enemy's massive computer support TACSAT communications stations will hide very little from the enemy. Even without ground station locations, jamming can be directed towards the satellites. When this is done, TACSAT communications nets working through the satellite are operating in a "stressed" mode. Jamming signals directed toward the satellite can originate far from the battlefield. Because of the directional antennas and frequencies used, jamming directed toward ground stations must come from nearby. Besides jamming, the enemy may attempt deception from either the ground or his own satellites. The enemy may attempt to insert false or misleading information and may also establish dummy nets operating through our satellites to cause confusion. In low- and mid-intensity conflicts however, there is a reduced electronic threat.

b. Defensive EW. TACSAT communications must operate within the REC environment just described. To do this, it is necessary to use available antijamming equipment and sound countermeasures. Communications discipline, security, and training underlie ECCM. Communications security (COMSEC) techniques give the commander confidence in the security of his communications. ECCM equipment and techniques provide confidence in the continued operation of TACSAT communications in a hostile EW or stressed environment. Particularly in TACSAT communications, the two are closely related techniques serving an ECCM role.

(1) COMSEC techniques protect the transmitted information. Physical security safeguards COMSEC materiel and information from access or observation by unauthorized personnel using physical means. Transmission security (TRANSEC) protects transmissions from hostile interception and exploitation. COMSEC and TRANSEC equipment protects most circuits. However, some TACSAT orderwires may not be secure. Technical discussions between operators can contain information important to the enemy. The nature of any mission gives the enemy access to critical information about commanders, organizations, and locations of headquarters. Although revealed casually on the job, this information is sensitive and must be protected. FM 34-62 covers signals security (SIGSEC) and information on COMSEC measures and techniques. TC 24-4A covers COMSEC applications for TACSAT operations.

(2) ECCM techniques protect against enemy attempts to detect, deceive, or destroy friendly communications. Changing frequency can defeat jamming. This requires the jammer to determine the new frequency and move to it. Meanwhile, the frequency can again be changed. This is the principle behind FH. Since it takes about 0.25 seconds for the earth station satellite-earth station trip, FH 4 times per second denies the jammer access to the satellite to earth link. FH at this rate must rely on automated equipment. FH at rates between 4 per second and 75 per second effectively avoids intercept and jamming when the enemy can receive only the downlink. With these low rates, bandwidth is still minimum while providing secure communications. FH forces the jammer to spread his energy (broadband jamming). This reduces the jammer noise density on any one channel. Wideband spread-spectrum modulation is another effective antijamming technique. With this technique, the information transmitted is added to a pseudorandom noise code and is used to modulate the TACSAT terminal transmitter. At the receiving end,

an identical noise generator synchronized to the transmitter is used. It generates the same noise code as the one at the transmitter to cancel the noise signal from the incoming signal. Thus, only the transmitted information remains. The spread spectrum signal can occupy the entire bandwidth of the satellite at the same time with several other spread spectrum signals. Each signal must have a different pseudorandom noise code. The noise code looks the same to the jammer whether or not it is carrying intelligence. This forces the jammer to spread his energy throughout the entire bandwidth of the random noise. This results in a reduced jamming noise density. The jammer has no knowledge of whether the jamming is effective.

c. Electromagnetic compatibility. Electromagnetic compatibility occurs when all equipment (radios, radars, generators) and vehicles (ignition systems) operate without interference from each other. With TACSAT communications terminals, a source of interference is the sun, a very strong source of broadband noise. However, factors such as location and antenna orientation can be controlled to eliminate this source of noise. For each equipment, use proper grounding techniques and follow safety considerations. When TACSAT communications terminals and other sets must be collocated, use a plan that prevents antennas from shooting directly into one another. Maintaining an adequate distance between antennas reduces mutual interference. Desensitization is the most common interference problem. This reduces receiver sensitivity caused by signals from nearby transmitters. Electromagnetic compatibility must be included in the plans for siting a TACSAT communications station.

d. Electromagnetic pulse (EMP). EMP is a threat to all sophisticated electronic systems. Under the proper circumstances, a major portion of the energy released during a nuclear detonation appears as an EMP. It has the same frequencies or wavelengths as those used by some of our TACSAT communications radios.

(1) EMP has two unique properties. First, EMP has a great “killing range.” EMP can disable electronic systems as far as 6,000 kilometers (3,720 miles) from the site of the detonation. Second, EMP can cause severe disruption and sometimes damage when other weapon effects are absent. A high-yield nuclear weapon, burst above the atmosphere, could be used to knock out a TACSAT communications system’s operational status without doing any other significant damage. The range of EMP is diminished if the weapon is detonated at a lower altitude within the atmosphere. An idea of the amplitude of EMP can be gained when we compare it with fields from man-made sources. A typical high level EMP could have an intensity which is 1,000 times more intense than a radar beam. A radar beam has sufficient power to cause biological damage such as blindness or sterilization. The EMP spectrum is broad and extends from low frequencies into the UHF band. The most likely EMP effect would

be stopping communications service temporarily. This can occur even without permanent damage. This delay could give an enemy enough of an advantage to change the outcome of the battle.

(2) The issue is protection against EMP. All TACSAT communications systems incorporate built-in features and techniques to counter the EMP effects. Shielding can further reduce the level of the EMP. Shielding is using equipment location and possible known directions of nuclear blasts to reduce EMP exposure. Shielding also depends on good grounding. Electronic systems depend on protection against EMP.