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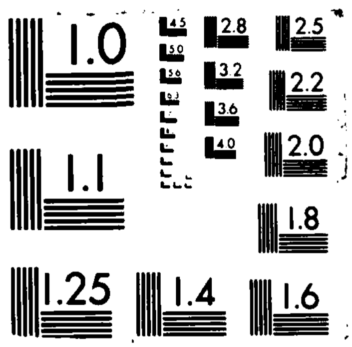
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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

THE OFFICER IN TACTICAL COMMAND AND TACTICAL DATA INFORMATION EXCHANGE SYSTEMS (OTCIXS/TADIXS) AND THE TRANSITION TO THE MILITARY STRATEGIC AND TACTICAL RELAY SYSTEM (MILSTAR)

by

Richard Banks Landolt

March 1987

Thesis Advisor: D.C. Boger

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The Officer in Tactical Command and Tactical Data Information Exchange Systems (OTCIXS/TADIXS) and the Transition to the Military Strategic and Tactical Relay System (MILSTAR)

by

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I. INTRODUCTION

A. BACKGROUND

In these days of evolving technology, planning for the next generation of a given technology or system and dealing with its new capabilities, limitations, and possible unintended consequences can never begin too soon. This thesis will discuss the Officer in Tactical Command Information Exchange Subsystem (OTCIXS) and its associated Tactical Data Information Exchange Subsystem (TADIXS), how they presently operate, and how they may operate in the future given the advent of the Military Strategic and Tactical Relay System (MILSTAR) and its improved satellite technology.

The OTCIXS subsystem evolved from a mid-seventies program known as "Outlaw Shark". In short, the OTCIXS was designed to provide two-way intra and inter-battlegroup communication links for command and control record traffic, via teletype (TTY), and for sending and receiving cruise missile targeting information through Tactical Data Processors (TDP). One-way return links were provided from battlegroups to Fleet Ocean Surveillance Information Centers and Facilities (FOSIC/FOSIFs) for contact reporting, and two-way links were provided between the Submarine Operating Authority (SUBOPAUTH) from Shore Targeting Terminals (STT) and the battle group for submarine coordination via TTY. Of primary importance to the user of the OTCIXS subsystem is its Over-the-Horizon Targeting (OTH-T) capabilities. As requirements for and improvements in OTH-T technology increased, a separate but closely related subsystem evolved, now known as TADIXS. [Ref. 1]

In a parallel fashion the Navy Fleetwide UHF Satellite Communication Program (FLTSATCOM) was faced with its own widening demands on its UHF frequency spectrum. One of the main causes of this increase in demand on fleet satellites was the growth of fleet requirements, stemming from improved warfare and computer processing technology, which manifested itself in the growth of information exchange subsystems, two of which are OTCIXS and TADIXS. [Ref. 2: p. 1]

These subsystems were all single channel users meaning one subsystem would tie up one satellite channel while in use. This was true until the advent of the Demand Assigned Multiple Access System or DAMA. The UHF DAMA system was designed to provide better use of satellite resources by multiplexing several users or subsystems and their data streams (as many as 22 nets) onto a single satellite channel by way of one high speed data stream. UHF DAMA has already been introduced into the fleet although all units are not equipped with the TD-1271B/U DAMA Multiplexor and its peripheral equipment. MILSTAR will not use the UHF DAMA system. Instead it will have its own DAMA system already integrated into each Army, Navy, and Air Force MILSTAR terminal. [Ref. 2: p. 4]

In order to more fully understand the advances in improved capability that the DAMA system has and will continue to provide and before we discuss the OTCIXS and TADIXS subsystems, some background on the evolution and present status of the Navy Fleetwide UHF Satellite Communication System as well as the growth of subsystems in general is necessary.

B. THE NAVY FLEETWIDE UHF SATELLITE COMMUNICATION SYSTEM

1. Gapfiller

Recently celebrating its tenth anniversary, the Navy Fleetwide UHF Satellite System began with the orbiting of its first satellite in 1976 given the name "Gapfiller." Gapfiller was the result of previous experiments to prove the feasibility of using geosynchronous satellites for telecommunications. [Ref. 3: p. 3]

A total of three Gapfiller satellites were deployed providing near total earth coverage. Gapfiller also demonstrated that equipment not only worked better in space, but would last longer as well, having far exceeded its planned service life of five years. In actuality, Gapfiller was a Navy UHF transponder package added to a MARISAT satellite under construction at the time Fleet Satellite, or FLTSAT, was approved in 1971. MARISAT, being a SHF satellite, had to be modified in order to incorporate this Navy transponder. [Ref. 3: p. 3]

As the name Gapfiller implies, it was designed to fill a temporary need and did so up until the Navy launched its first FLTSAT satellite in February of 1978 (see Table 1-1). It successfully shortened the time between conception and successful operation of the FLTSAT program. This borrowed time helped to insure a successful Navy satellite communication program, providing early hands-on experience and developing needed expertise in this field. [Ref. 3: p. 3]

TABLE 1-1

NAVY SATCOM SATELLITES COMPARED
[Ref. 2: p. 3]

	GAPFILLER	FLTSAT *	LEASAT *
Year introduced	1976	1978	1984
Expected service life (years)	5	5+	7+
Number in constellation	3	4	4
25 kHz channels per satellite	2	10	7
Wideband 500 kHz channel	1	1	1
Weight (kilograms)	655	1860	1330

* Air Force SATCOM 5kHz channels not shown.

2. The Leased Satellite Follow On

The Leased Satellite (LEASAT) program was the follow-on to FLTSAT but was designed to replace Gapfiller and be augmented by the already emplaced FLTSAT satellites. The LEASAT satellite is much lighter than its FLTSAT counterpart and possesses a longer expected life span as well. Two LEASAT satellites were put into orbit in late 1984 and are operational. The combination of FLTSAT and LEASAT provide the fleet with a reliable near round-the-globe capability today (see Figure 1-1). [Ref. 3: p. 3]

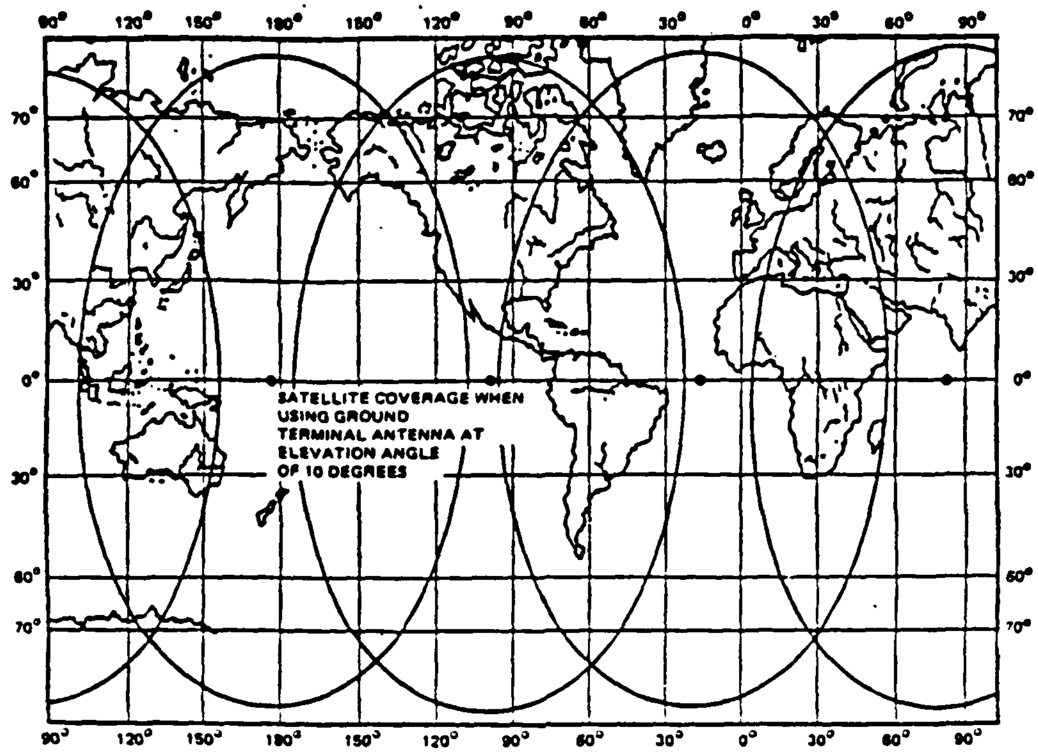
C. THE GROWTH OF THE SUBSYSTEM

1. Background

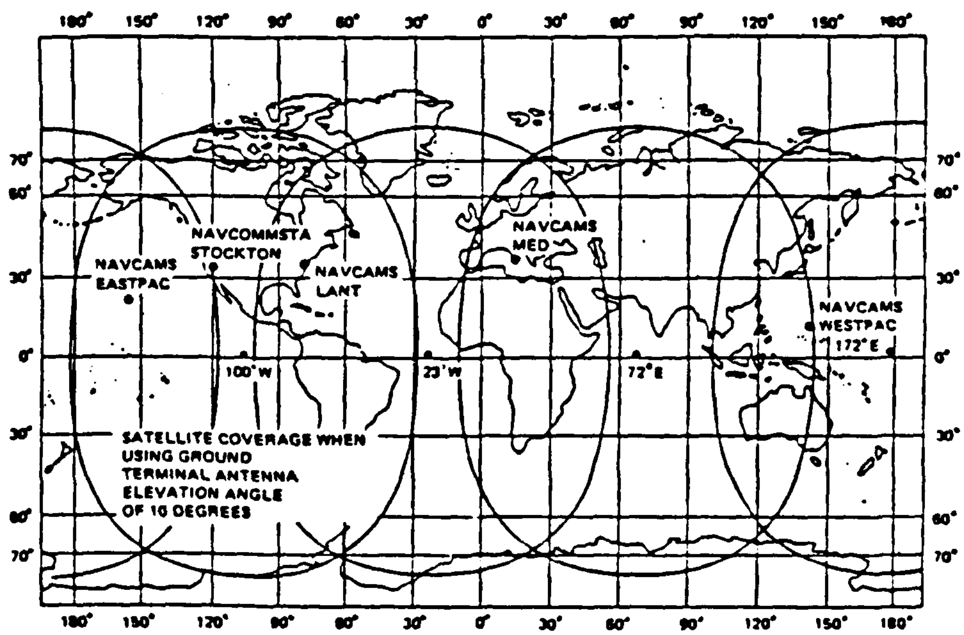
Before the state of the art of communications reached the satellite stage, the primary means of transmitting over long distances was via High Frequency or HF radio. However, even with multiplexing, the HF spectrum quickly reached saturation levels due to the competitive requirements of both military and commercial needs. Additionally, the quality of HF transmissions are highly susceptible to both predictable (daily and seasonal) and unpredictable variation (sunspot activity and atmospheric changes). [Ref. 2: p. 1]

2. Subsystem Growth

The advent of the geosynchronous satellite allowed for the use of the line of sight UHF/EHF frequency range which



LEASAT Coverage Areas



FLTSATCOM Coverage Areas

Figure 1-1 LEASAT and FLTSAT Coverage Areas [Ref. 3: p. 3] in turn allowed for higher speed data links without the limitations associated with HF communications. However, fleet requirements continued to grow at a faster rate than satellite technology could increase capacity. Improved warfare technology as well as satellite communication capabilities led to the development of more complicated and specialized Navy subsystems. [Ref. 2: p. 1] Here listed are the subsystems, with a brief description, which are currently planned or already operating under a DAMA mode.

a. Tactical Intelligence Subsystem (TACINTEL)

This subsystem provides for broadcast screening and rapid exchange of Special Intelligence (SI) communications between shore stations and ships. Its computerized message processing allows for automatic transmission and receipt via satellite under a controlled environment.

b. Secure Voice Subsystem (SECVOX)

SECVOX provides narrowband secure voice (NBSV) communications between operating units and shore based facilities via two UHF satellite channels.

c. Common User Digital Information Exchange Subsystem (CUDIXS)/Naval Modular Automated Communications Subsystem (NAVMACS)

These two subsystems combine to form a communications network for General Service (GENSER) message traffic between shore installations and shipboard platforms.

d. Teletypewriter Subsystem (ORESTES)

This is an expansion of existing teletypewriter communication networks, but uses satellites as relay stations.

e. Fleet Satellite Broadcast (FSB)

FSB is an expansion via satellite of Fleet Broadcast transmission which have been the central communications medium for operating Naval units.

f. Submarine Satellite Information Exchange Subsystem (SSIXS)

SSIXS provides a high speed digital data link between shore installations and submarines.

g. Tactical Data Information Exchange Subsystem (TADIXS)

TADIXS provides a shore-to-ship capability for the transmission of Over-the-Horizon Targeting (OTH-T) information to cruise missile equipped platforms.

h. Officer in Tactical Command Information Exchange Subsystem (OTCIXS)

OTCIXS provides a two-way satellite link to support Battle Group Over-the-Horizon (OTH) command and control tactical targeting communication requirements. [Ref. 2: p. 8]

These increases in general service and specialized subsystem requirements were quickly able to fill the increased capabilities provided by the Navy's UHF SATCOM program. Additionally, many of the satellites involved in this program were also reaching the end of their useful service lives (see Table 1-1) forcing the Navy to plan for a transition to a new satellite constellation with its improved capabilities as well as configured limitations. [Ref. 2: p. 1]

The LEASAT system does not have enough UHF channels to meet the Navy's future needs. The lack of available channels coupled with the increase in Navy needs were the motivation behind the development of DAMA. The thrust of DAMA is its ability to use channels more effectively by Time Division Multiplexing (TDM) several of these previously described subsystems onto a single satellite channel. This has the advantage of making better use of satellite resources by having several subsystems use one channel simultaneously, without mutual interference betweeen or among subsystems. DAMA combines the data stream from independent sources into a continuous high speed data stream. This DAMA multiplexed data stream is grouped into frames and transmitted to the satellite. [Ref. 2: p. 4]

D. OBJECTIVES

The next generation of satellites, a constellation entitled MILSTAR for Military Strategic and Tactical Relay, is in the critical design review process. Its projected initial operational capability is for sometime in the early 1990's. In addition it is designed to be more survivable and will process signals instead of merely retransmitting them as do current FLTSAT satellites. Inherent in this ability to process signals come certain limitations which must be considered to successfully transition current Navy operations and their supporting subsystems onto MILSTAR. It is the objective of this thesis to discuss the capabilities and limitations of MILSTAR for OTCIXS and TADIXS and to provide conclusions and possible recommendations on achieving a successful transition from the current FLTSATCOM system to MILSTAR.

E. ORGANIZATION

The chapters of this thesis give a description of OTCIXS and TADIXS, their mission, modes of operation, etc., and how the Navy currently communicates through them. Chapter II discusses the OTCIXS subsystem followed by TADIXS in Chapter III. In Chapter IV, MILSTAR will be discussed in more detail, providing insight as to its capabilities and limitations. Finally in Chapter V, analysis and recommendations will be considered concerning the circumstances under which OTCIXS/TADIXS might transition to MILSTAR and how to best utilize MILSTAR's resources should transition occur.

II. THE OFFICER IN TACTICAL COMMAND INFORMATION EXCHANGE SYSTEM (OTCIXS)

A. THE MISSION

The mission of the Officer in Tactical Command Information Exchange Subsystem (OTCIXS) is to provide dependable, beyond line-of-sight via satellite, two-way communications between surface ships, submarines, and shore installations on a near real-time basis. On an OTCIXS channel, subscribers have the ability to exchange teletype, data link, and secure voice messages. More specifically, provides two-way intra and inter-battle group communications in order to pass command and control record traffic (teletype) or exchange surveillance and targeting information using the Tactical Data Information Exchange Subsystem (TADIXS) information via Tactical Data Processors (TDP). Additionally, it is used to provide a one-way communications link from the battle group to Fleet Ocean Surveillance Intelligence Centers and Facilities (FOSIC/FOSIF) for contact reporting, also done on a TDP, and to provide a two-way communications link between Shore Targeting Terminals (STT) and the Battle Group for submarine targeting coordination by way of teletype (see Figure 2-1). [Ref. 5: p. 1-1]

Another method of communicating this type of information is to leave the OTCIXS teletype and TDP network and select

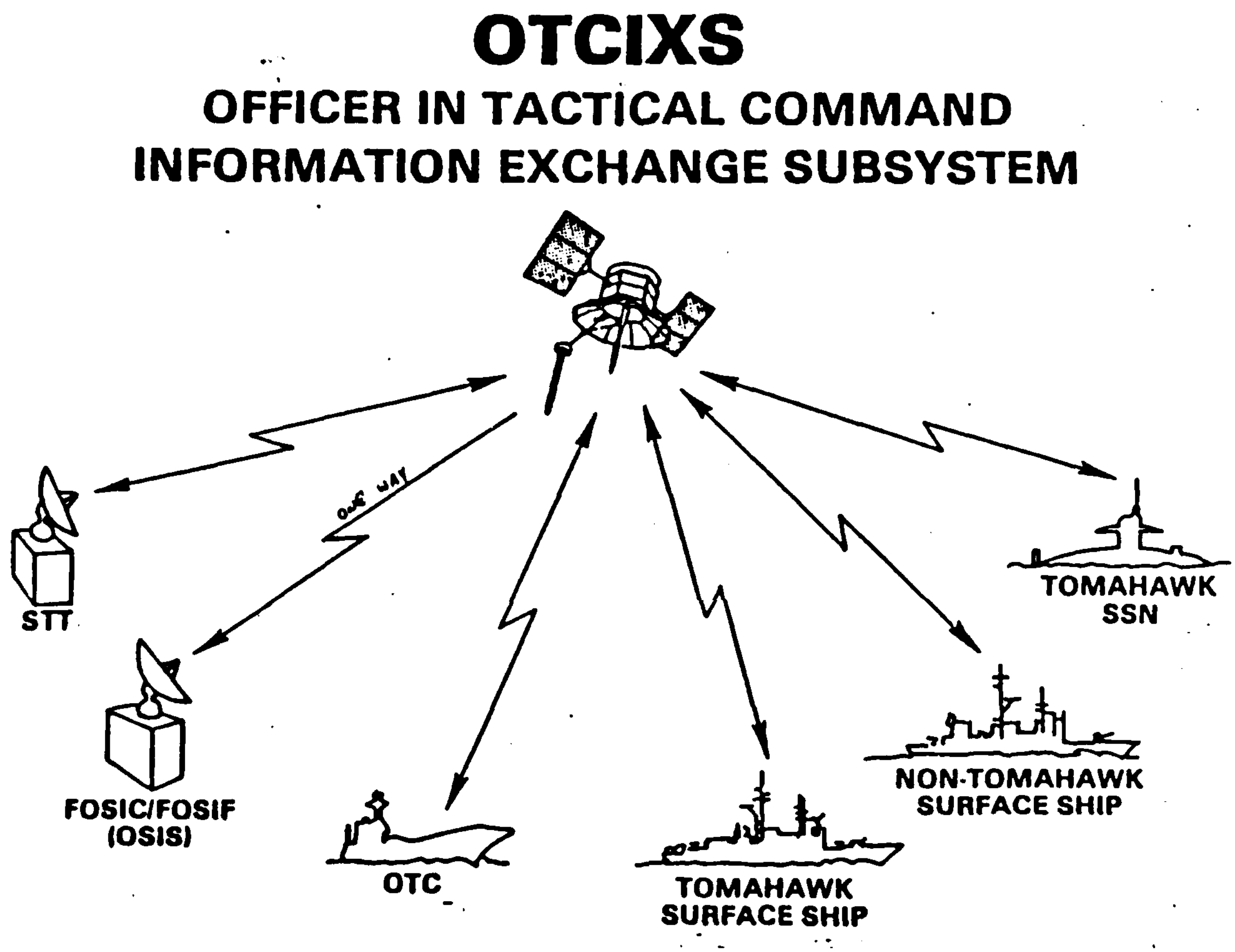


Figure 2-1 Officer in Tactical Command Information Exchange Subsystem [Ref. 1]

one of the several Fleet Satellite Communications (FLTSATCOM) Secure Voice Channels (SECVOX) and, using digital voice communications, interact with other FLTSATCOM Secure Voice users. Subsurface units have the capability to communicate over the Submarine Satellite Information Exchange Subsystem (SSIXS) network. This thesis will focus primarily on the OTCIXS/TADIXS subsystems, discussing aspects of some of the other various subsystems such as SSIXS only as they become relevant. [Ref. 5: p. 1-1]

B. CONCEPT OF OPERATION

The OTCIXS network consists of up to 9999 subscribers worldwide that are operating between 70 degrees north and south latitude. This limitation is due to the geosynchronous position of FLTSAT satellites over the earth. It uses a 25 KHz UHF channel at 2.4 kpbs which will be compatible with the currently under implementation Demand Assigned Multiple Access (DAMA) system in a two-way or half duplex communcation mode. [Ref. 5: p. 1-1]

The OTCIXS, as well as the SSIXS and FLTSATCOM networks, use geosynchronous satellites as relays to receive and then transmit the message traffic among subscribers. Each of these subsystem networks operates independently of the others. However, teletype, TADIXS, and OTCIXS all can be operated at the same time if one channel is dedicated to each net. Eventually, these networks will be "Damatized" which in effect means that they will allow several subsystems to share one satellite channel and thus save on a satellite's resources. Initial Operational Capability (IOC) of DAMA has occurred as of January 1986 with the transitioning of TACINTEL and SECVOX. [Ref. 2: p. 1]

The OTCIXS network depends on a designated net control station within each satellite's footprint to automatically coordinate access to the network. The OTCIXS network uses gateway facilities to transfer selectable message traffic from one satellite's network to an adjacent satellite's network when a unit in one satellite's footprint must communicate with an addressee in another satellite footprint (see Figure 2-2). [Ref. 5: p. 1-2]

1. The Satellite Link Controller or ON-143(V)6/USQ

The central point for communication control in the OTCIXS subsystem is the satellite link controller or ON-143(V)6/USQ. The satellite link controller provides satellite, line-of-sight (LOS) and inter-ocean (gateway) capability to communicate within the OTCIXS network, satellite and LOS for the SSIXS network, and the FLTSATCOM secure voice (SECVOX) network. Its digital processor programs provide the control required to interact with the operator and allow the operator to use the same suite of equipment for all three (OTCIXS, SSIXS, SECVOX) communication networks. Different program versions are required for a satellite link

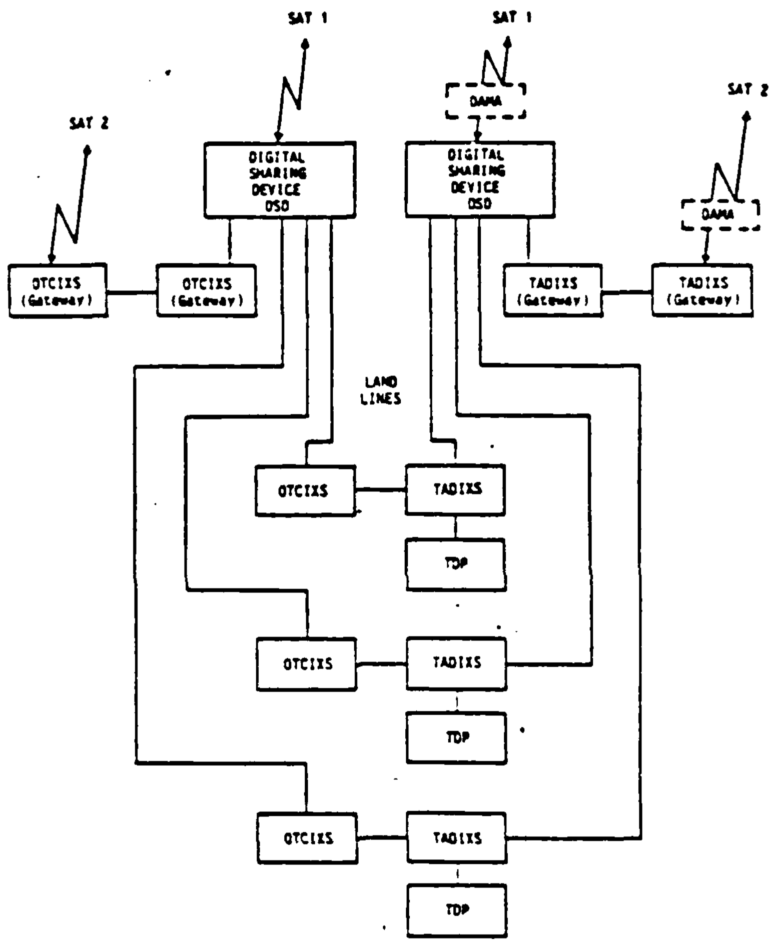


Figure 2-2 Typical OTCIXS Shore Installation [Ref. 5: p. 1-6]

controller equipped with a Combat Control System (CCS), used on submarines, instead of the TDP used on ships, and for units functioning as inter-ocean gateways. [Ref. 6: p. 3-1]

The link controllers' operator controls have the capability to select the network status, radio status, net control status, and other parameters associated with message broadcasting. It has a control panel that displays these parameters and current information regarding network and alert status. The link controller provides built-in test capabilities as well, to detect and isolate hardware faults and interface failures automatically upon system initiation as well as manually by the operator. Test modules and system self-checks are aids here in troubleshooting any system shortcomings. [Ref. 6: p. 3-1]

2. OTCIXS Network Operation

Each subscriber has the capability to operate as a net control station, and/or subscriber, since all subscribers possess the ON-143(V)6/USQ link controller. The OTC network enables multiple subscribers within LOS or within a single satellite footprint to exchange teletype and data link data on a half-duplex satellite channel. Each surface non-gateway OTCIXS network member is able to transmit or receive teletype messages, transmit or receive data link, data, and transmit or receive OTCIXS scheduled broadcasts. [Ref. 5: p. 1-2] To enlarge on these modes the following is provided.

a. Teletype

The ON-143(V)6/USQ provides automated broadcast capabilities accepting input messages from a teletypewriter, paper tape, or a remote plasma display and broadcasting to other net members. Receiving subscribers, specified as addressees, shall receive and store (buffer) these messages until they can be output at the teletypewriter. The operator specifies addressees, precedence, and classification of messages. The transmitting subsystem automatically gains control and transmits all the buffered teletype messages. Receiving subsystems specified as addressees store these messages until they can be outputted on the teletypewriter or plasma display. [Ref. 5: p. 1-2]

b. Data Link

The non-gateway satellite link controller is capable of interfacing with either or two different types of external computer systems: a TDP or CCS. The TDP interfaces through an I/O multiplexor called a Sensor Interface Unit (SIU). The SIU interfaces with the satellite link controller according to one of two differing protocols, one program for interfacing with a TDP and the other if needed for an SIU. Upon TDP or CCS operator request, the satellite link controller can automatically gain control of the satellite channel for transmission of data link data and transmit the data to other OTCIXS subscribers to be output to other external computer systems. Again the TDP or CCS operator specifies precedence, addressees, and classification of the data link transmission. [Ref. 5: p. 1-2]

c. Scheduled Broadcast

Data link broadcasts are augmented by the scheduled broadcast capability. This allows Shore Targeting Terminals (STT) the ability to schedule broadcast of Over-the-Horizon/Detection Classification & Targeting (OTH/DC&T) information to deployed subscribers equipped with OTCIXS. The TDP's satellite link controller is able to provide network access at times pre-selected by the OTC operator for scheduled broadcasts. While interrupting any immediate precedence broadcasts at the scheduled time, it will not interrupt 'Flash' message traffic. The satellite link controller automatically gains control of the satellite channel and performs as any data link transmission. The use of the scheduled broadcast instead of the regular data link form of transmission is left to the choice of the TDP operator. [Ref. 5: p. 1-3]

3. Gateway Functions

At designated ground nodes within each satellite footprint, shore-based processor pairs (coprocessors) are provided to allow footprint-to-footprint worldwide OTCIXS communications. Inter-ocean OTCIXS teletype and data link message communications are possible with the operation of the OTC gateway processors. For each satellite footprint, two satellite link controllers perform as gateways, one for each adjacent footprint. A gateway processor of one footprint is hardwired to the gateway processor of the adjoining footprint. Using an operator-entered guardlist of addressees, each gateway processor screens all incoming OTC network traffic against these lists. The satellite link controller passes to its adjoining processor all messages on the guardlist in its footprint and automatically gains control of its own satellite channel to broadcast messages. Each gateway's satellite link controller will communicate with another satellite while being able to directly communicate with the other gateway. Each gateway can act as either the net control station or as a regular OTCIXS subscriber. If in the subscriber mode, the gateway provides the operator with access to OTCIXS teletype data only. With the processor in the net control station mode, the gateway provides inter-ocean screening for OTCIXS teletype, data link, and scheduled broadcast message traffic. [Ref. 6: p. 3-5]

C. SPECIFIC FUNCTIONAL CAPABILITIES

1. Communications Input/Output

The ON/143(V)6/USQ or Satellite Link Controller is capable of sending and receiving message traffic originated by teletypewriter, remote plasma display, and paper tape. Messages sent from any source shall be output at the teletypewriter and/or remote plasma display of the receiving subscriber (see Figure 2-3). KG-35/36s are not compatible with the KG-84s. [Ref. 5: p. 3-4]

All message traffic entered into the satellite link controller is transmitted in the broadcast mode. The OTCIXS broadcast mode consists of redundant transmissions of each message curently stored in the transmit queue of the satellite link controller. The receiving satellite link controllers select the best elements of the redundant transmissions of the broadcast for each message and pass the composite, complete message to the output device. [Ref. 5: p. 3-4]

2. Voice Capability

The FLTSATCOM Secure Voice Network allows subscriber-to-subscriber voice transmission. The satellite link controller is capable of transmitting or receiving voice traffic originating on a narrow band audio digitizer, or vocoder, over the FLTSATCOM Secure Voice channel. In this mode the satellitelink controller acts as the interface between the voice digitizer (Vocodor), the cryptographic equipment, and the radio. Voice transmissions are initiated manually using the operator-actuated push-to-talk button. Voice receptions will be detected by the satellite link controller and passed to the voice digitizer. Voice communications are available to all satellite link controllers monitoring this satellite's channel. [Ref. 6: p. 3-6]

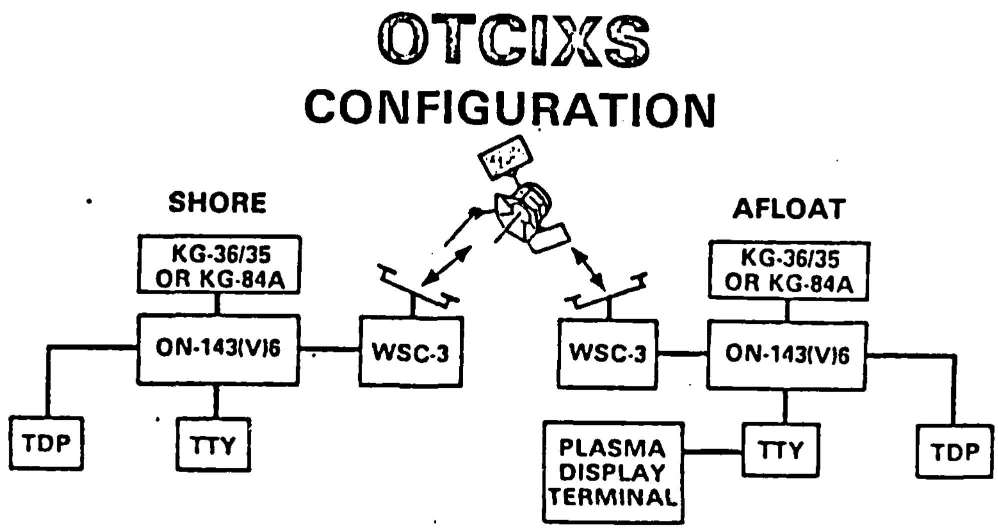


Figure 2-3 OTCIXS Configuration
[Ref. 1]

3. Data Link

The satellite link controller is capable of transmitting and receiving data link information over the OTCIXS RF link that is preprocessed by an external TDP or CCS. This data link information transfer capability is the most vital part of the satellite link control. The OTCIXS data link interface permits data tarnsfer from one data link processor to another via the OTCIXS network. [Ref. 5: p. 3-4]

Data link traffic passed to the satellite link controller is transmitted in the broadcast mode, which consists of redundant transmission of each data link message. The receiving satellite link controller selects the best elements of these transmission for each message and passes the composite message to its external TDP via the attached satellie link controller. [Ref. 5: p. 3-4]

OTCIXS net members without a TDP have the capability of receiving data link information but are only able to print man-readable messages at the teletype printer and/or remote plasma display. This function is operator-selectable on non-TDP systems, and is available as a degraded mode of operation on TDP-equipped systems if the TDP is down. [Ref. 5: p. 3-5]

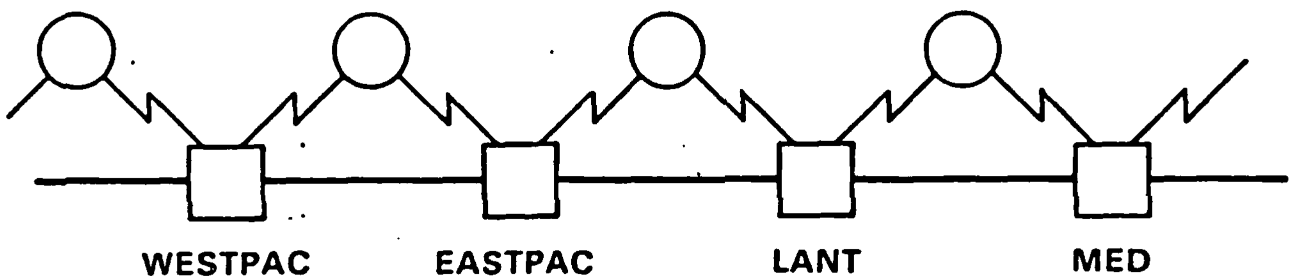
4. Scheduled Broadcasts

The satellite link controller is capable of transmitting andreceiving either teletype or data link messages over the OTCIXS RF link at pre-scheduled times. Data link messages are preprocessed by either a Shore Targeting Terminal (STT) or an external TDP. Teletype messages can be identified as scheduled broadcast messages and are entered at the keyboard by the OTCIXS operator. This information transfer capability is another integral part of the OTCIXS link control discipline. Combat Control Systems (CCS) are not able to provide scheduled braodcast data. This data link teletype information is identical to other message transfers except it is broadcast at the predetermined times. In order to ensure on-time broadcasts this scheduled broadcast must preempt all immediate precedence tranmission. [Ref. 5: p. 3-5]

5. Inter-Ocean Screening

Two satellite link controllers connected via their TDP ports and using a special, symmetrical version of the ON-143(V)6/USQ/TDP interface perform the inter-ocean screener (gateway) function. These gateways provide the means for transferring selectable OTCIXS teletype, data link, and scheduled broadcast messages from satellite footprint to satelite footprint and thus world wide if necessary (see Figure 2-4). Scheduled broadcast messages received

GATEWAYS



- PROVIDE C2/OTH-T TRAFFIC TO UNITS OPERATING OUTSIDE LOCALLY SUPPORTED SATELLITE FOOTPRINT
  - — DISPERSED BG UNITS
  - — BACK UP SHORE SITES

Figure 2-4 GATEWAYS
[Ref. 1]

at a gateway controller will be transferred as either teletype or data link messages to the connected gateway controller. Additionally, each gateway processor may act as the net control station if required. Each gateway processor may be an OTCIXS subscriber but can only exchange teletype message traffic. [Ref. 5: p. 3-5]

D. COMMUNICATIONS PROCESSING AND CONTROL

1. Network Processing Operations

The OTCIXS network can consist of up to 9999 subscribers worldwide. Each subscriber is assigned one unique four-digit subscriber identification number (SID). Each teletype message, data link transmission or scheduled broadcast may be addressed to a single subscriber, a group of subscribers, or all subscribers reachable within any network. Each OTCIXS subscriber may enter a guard list of SID's to monitor traffic addressed to other subscribers. Messages can thus be routed to an identified group of subscribers by providing these subscribers with a common SID for their guard lists. [Ref. 5: p. 3-5]

For OTCIXS message traffic, gateway processing provides the means to relay traffic from originator to satellite to ground node to satellite thus providing the required near real-time worldwide availability. Each OTCIXS gateway processor has a guard list of SID's to determine how best to process OTCIXS messages. [Ref. 5: p. 3-6]

Teletype messages addressed to a gateway are processed and output at the teletype associated witb the gateway system. No gateway processor may join the FLTSATCOM voice or SSIXS networks. [Ref. 5: p. 3-6]

Each transmission (teletype or data link) is assigned to one of two link precedence levels, immediate or flash. The OTCIXS operator specifies the precedence of teletype messages entered for transmission; the TDP operator specifies the precedence of data link messages entered. Scheduled broadcast messages only carry the precedence of immediate. [Ref. 5: p. 3-6]

Each message is assigned a security classification. The classification of these messages entered from the TDP is determined by line analysis. Subscribers are not restricted from receiving teletype message, data link, or scheduled broadcast transmissions while in emission control (EMCON) status. [Ref. 5: p. 3-6]

2. Network Control Capabilities

Within each OTCIXS network, the satellite link controller has the capability of operating as a Net Control Station (NCS) and/or subscriber. Procedurally, a selected station is designated as the authorized net control station for a given satellite footprint. This net control station allocates link time to network participants thus enforcing the net control discipline. At no time may a subscriber transmit without NCS permission. [Ref. 5: p. 3-6]

The use of link time is automatically coordinated by the net control station satellite link controller. It is based on subscriber requests and the two precedence levels previously discussed. Only one mode of operation (teletype, data link, or scheduled broadcast) is permitted at any one time because the satellite link controller can only monitor a single channel at a time. [Ref. 5: p. 3-6]

Net control permits the preemption of immediate precedence transmission to allow for flash precedence transmission and permits the scheduled broadcast with its immediate precedence traffic to preempt any other immediate precedence transmissions. Failure of a subscriber to maintain active access to the OTCIXS net does not prevent the subscriber from reentering the net. [Ref. 5: p. 3-6]

E. MAJOR COMMUNICATION EQUIPMENT

1. The Satellite Link Controller or ON-143(V)6/USQ

The satellite link controller consists of a Central Processing Unit (CPU), its memory and programmable interfaces designated Dynamically Adaptive Receiver Transmitter (DART) modules. Components of the satellite link controller communicate via a high speed data bus. All satellite link controller programs reside in the Read Only Memory (ROM) of the CPU. Upon system initialization, programs for DART modules are downloaded from the ROM to the DART modules. Program functions are defined in such a way that the CPU performs the major system functions and the DART module programs perform the interface functions. [Ref. 6: p. 3-9]

2. <u>The WSC-3/WSC-5 Transceiver</u>

The WSC-3 or WSC-5 transceiver is used for all transmitting and receiving. The satellite link controller automatically selects the radio frequency by selecting one of four available channels. The satellite link controller is also able to provide a transmitting clock to the radio or synchronize with a transmitting clock provided by the radio. The satellite link controller synchronizes with the radio receive clock to receive data. To ride through possible short signal fades when the radio clock is invalid, the satellite link controller can perform a clock function to keep the system stable for short durations. Fades are tolerated in the SSIXS for up to three seconds while up to 500 milliseconds in other modes. Longer fades than this may force a reestablishment of the clock function. [Ref. 6: p. 3-9]

The satellite link controller controls a radio key line to enable the WSC-3 or WSC-5 transmitter. It also monitors the 'channel busy' indicator from the radio which, used in conjunction with the cryptographic equipment, senses a reception in order to determine channel availability. [Ref. 6: p. 3-16]

3. The CV-3333/A Voice Operated Coder (VOCODER)

The Voice Operated Coder (VOCODER) interfaces to the vocoder DART module via a 2400 bps synchronized interface. A single discrete line from the vocoder is used to sense the state of the push-to-talk button on the vocoder handset. The satellite link controller controls a discrete line to the vocoder to command it to send frames on what is called the voice digitizer data stream. Here during voice transmissions, the satellite link controller accepts digitized voice data from the vocoder and echoes it to the vocoder handset file allowing the user to hear him talk while transmitting. During voice receptions, received data is passed to the vocoder to generate the audio. [Ref. 6: p. 3-15]

4. Communications Encryption/Decryption

All data exchanged by OTCIXS subscribers is cryptographically secure although units using cryptographic equipment may not communicate with units using TSEC/KG-84A cryptographic equipment. [Ref. 6: p. 3-15]

F. CONCLUSION

We have now covered the basic network operational concepts of the OTCIXS both generically and in more detail. We have also covered the major components and equipment associated with it. However, the primary force multiplier of this subsystem involves its support of the associated Tactical Data Information Exchange Subsystem (TADIXS). It is now time to look at this subsystem in detail.

III. THE TACTICAL DATA INFORMATION EXCHANGE SYSTEM (TADIXS)

A. THE MISSION

The Tactical Data Information Exchange System (TADIXS) is designed to support the exchange of Over-the-Horizon Targeting (OTH-T) information between shore and fleet-based computer systems, collectively referred to as Tactical Data Processors (TDP), which support Navy cruise missile operations. [Ref. 7: p. 3-1]

B. TADIXS SYSTEM FUNCTIONAL AREAS

TADIXS components, landlines, and satellite links combine to provide three major functions. These functions are:

1. Shore Link Communications; to include all communications control to connect shore users and transfer data to/from the routing nodes. Also included in this is a standard interface to the TDP in order to provide encryption/decryption, error control, and the formatting of data to/from the OTH-T routing control function.

2. OTH-T Routing; to include the processing of the addressing information accompanying message data, the maintenance of system routing information, and the storage and forwarding of data to the designated circuit for delivery.

3. Satellite Link Communications; constituted by the control of satellite links, including contention for access, encryption/decryption, error control, and the formatting and transfer of data. [Ref. 7: pp. 3-11, 13]

C. CONCEPT OF OPERATION

TADIXS operates on a worldwide basis between 70 degrees north and south latitudes and is designed to accommodate up to a thousand subscribers (addressees). Up to 16 of these addressees in a satellite footprint may be shore subscribers capable of both transmitting and receiving. Each TADIXS network operates either through DAMA or over a dedicated satellite channel (Non-DAMA mode). In the former mode, the satellite link controller accesses through the DAMA multiplexer (TD-1271B/U). In the latter the TADIXS satellite link controller interfaces directly with the UHF SATCOM radio, the WSC-3 or WSC-5. The advantages of operating through DAMA are that it allows TADIXS to share a satellite channel with other subsystem networks operating independently. Operations in a Non-DAMA mode will continue to occur until the fleet is fully equipped with the DAMA multiplexor. [Ref. 8: p. 1-1]

1. Program Capability

As with the OTCIXS, the central point of communications control resides with TADIXS ON-143(V)6/USQ. With this the operator has the capability to select his station as a TADIXS transceiver (available on selected shore sites only) or receiver if shipboard as afloat subscribers are operationally capable of receiving messages only. Subscribers at shore sites use the TADIXS link to broadcast OTH-T messages originating from or destined to Tactical Data Processor (TDP) systems. [Ref. 8: p. 1-2]

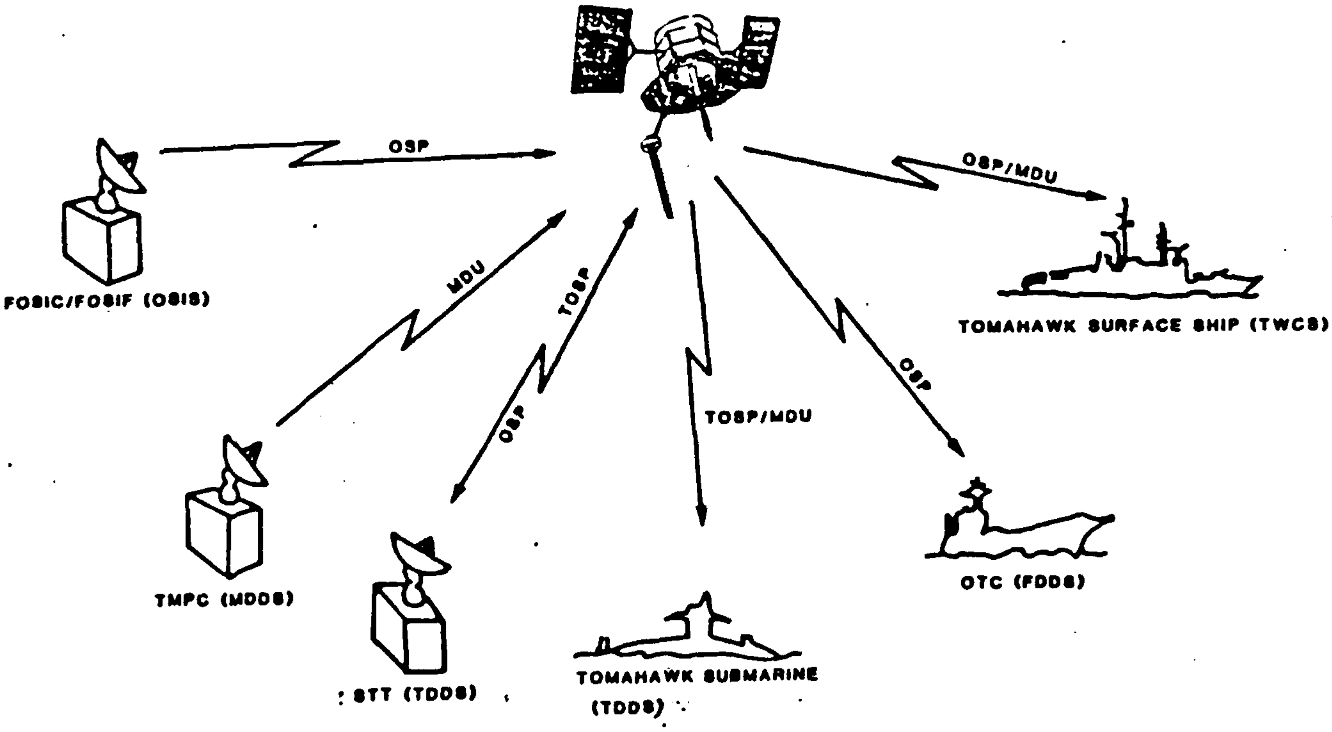
2. TADIXS Shore Configuration

There are two types of TADIXS shore configurations: shore broadcast sites and Tactical Gateway Facilities (TGF). Broadcast sites interface with a peripheral TDP which allows for both the transmission and reception of OTH-T messages. Here the subscriber's TADIXS ON-143(V)6/USQ interfaces with an OTCIXS ON-143(V)6/USQ satellite link controller thus allowing OTH-T messages and message acknowledgements to be received over the OTCIXS network from afloat subscribers. [Ref. 8: p. 1-2]

A gateway site also provides the necessary interface between two UHF SATCOM radio channels. It functions only to pass messages from one satellite footprint to another and is thus located within the overlap of these two footprints. It is the gateway technology that, if necessary, allows for the worldwide exchange of TADIXS message traffic. Either of these shore configurations may act as a TADIXS Net Control Station (NCS) if desired. [Ref. 8: p. 1-2]

3. Afloat Configuration

In the TADIXS network, shipboard platforms have a receive only capability. As in shore sites, each TADIXS ON-143(V)6/USQ is hardwired to an OTCIXS ON-143(V)6/USQ allowing afloat subscribers to route OTH-T messages over the OTCIXS net to TADIXS shore broadcast sites (see Figure 3-1). [Ref. 8: p. 1-4]



3-2

Figure 3-1 TADIXS OTH-T Data Transfer Requiements
[Ref. 7: p. 3-2]

D. SPECIFIC FUNCTIONAL CAPABILITIES

1. Communicaton Input and Output

The satellite link controller is capable of transmitting and receiving data link information that is preprocessed by an external TP and configured for direct transmission on the TADIXS RF link. The TADIXS/Data link interface permits data transfer from one ON-143(V)6/USQ to another via the TADIXS network. Data link traffic passed to the interconnecting group is transmitted in the broadcast mode which consists of two consecutive transmissions of each data link message. The receiving interconnecting group selects the best elements of the two transmission broadcasts for each message to its external TDP. [Ref. 8: p. 3-3]

2. Communications Processing and Control

a. Network Operations

As noted earlier TADIXS network subscribers consist of a combination of shore broadcast and gateway sites capable of both transmitting and receiving. Afloat platforms are capable of receiving only. Each subscriber is assigned a unique 3-digit Subscriber Identification (SID) and an operator can enter a guardlist made up of these SIDs in order to receive message traffic. A subscriber's satellite link controller will automatically discard received messages which are not addressed to any SID on its guardlist. [Ref. 8: p. 3-3]

b. Net Control Capabilities

Each of the TADIXS shore subscribers have the capability of operating as a Net Control Station (NCS). Procedurally, a selected station shall be designated as the authorized NCS for each satellite footprint. The NCS allocates link time to network subscribers as part of the net control discipline. At no time may a subscriber transmit without permission from the NCS. [Ref. 8: pp. 3-3, 4]

The use of link time is automatically coordinated by the NCS interconnecting group according to a query-response link allocation technique. The NCS sequentially polls each active net transmitter for a transmission request. Each subscriber ready to transmit must wait its turn and only transmit when polled. After a subscriber completes a first transmission it will immediately be polled for a redundant transmission to insure the accurate reception of the message. There is a periodic link time slot in which new transmitting s·bscribers entering the net can send a request to the net control station to be added to its polling list. A subscriber which successively fails to respond to the net control polling with at least a "No Traffic" acknowledgement is dropped from the list of active net shore subscribers. Should the polling NCS be degraded or destroyed, communication plans call for an alternate NCS to assume link control. [Ref. 8: p. 3-4]

3. Communications Transmission and Reception

All transmissions and receptions are presently accomplished via current Navy UHF FLTSATCOM assets. The baseband equipment has single channel capability, enabling the satellite link controller to either access the satellite directly through the WSC-5 or WSC-3 radio (Non-DAMA) or indirectly through a DAMA TD-1271U/B multiplexer. DAMA will be discussed more thoroughly in Chapter IV. [Ref. 8: p. 3-4]

E. GENERAL ADMINISTRATIVE DESCRIPTION

To overview, TADIXS is designed to provide worldwide connectivity among OTH-T users by way of both satellite links and landlines connecting computer controlled switching nodes. A more common name for these nodes is the TADIXS Gateway Facility (TGF). Shore user systems interface via landlines with the TGFs which are located at the four Naval Communications Area Master Stations (NAVCAMS) located in Naples, Norfolk, Hawaii, and Guam, as well as Naval Communications Station (NAVCOMMSTA) Stockton, California. These TGFs presently interface with Fleet Satellite (FLTSAT) or Leased Satellite (LEASAT) assets providing the necessary routing control in their respective coverage areas. [Ref. 7: p. 3-1]

The term TDP has been used thus far in a collective sense to simplify explanation of the more technically oriented functions TADIXS performs. However, there are various specific platforms and facilities, all of which possess these TDPs, that need to be discussed in more depth for the reader to truly appreciate the force multiplying tactical manipulation of OTH-T data this system can provide. These system platforms and facilities and their primary system functions (summarized in Table 3-1) will now be discussed in more detail. [Ref. 7: p. 3-1]

The following sections will describe individual user systems (both afloat and ashore) and their communication requirements, communications assets, and TADIXS components serving to interconnect user communities.

1. Shore Systems

Shore-based TDP facilities employing TADIXS services are:

a. Theater Mission Planning Centers (TMPC)

b. Fleet Ocean Surveillance Information Center/Facility (FOSIC/FOSIF)

c. Submarine Operating Authority (SUBOPAUTH)

a. Theater Mission Planning Centers (TMPC)

There are two primary TMPCs to the TADIXS network. One located at Commander-in-Chief, Atlantic (CINCLANT) and the other at Commaander-in-Chief, Pacific (CINCPAC). A third TMPC participates as a central support facility providing

TABLE 3-1

PRIMARY TDP CONFIGURATIONS

Table 3-1. Primary TDP Configurations

TDP Location	System Title	Function supported by TADIXS
Theater Mission Planning Center (TMPC)	Mission Data Distribution System (MDDS)	Broadcast of Mission Data Updates (MDU) to cruise missile surface ships and submarines
Fleet Ocean Surveillance Information Center/Facility (FOSIC/FOSIF)	Ocean Surveillance Information System (OSIS)	Broadcast of Ocean Surveillance Product (OSP) to Tactical Command and cruise missile surface ships
Submarine Operating Authority (SUBOPAUTH) Shore Targetting Terminal (STT)	Tactical Data Display System (TDDS)	Broadcast of Tailored OSP (TOSP) to cruise missile submarines
COMTHIRDFLT Tactical Data Display System Research and Development (R&D) Site	Tactical Data Display System (TDDS)	Receipt of OSP for Test and Evaluation (T&E) of OTH-T messages for cruise missile support
Tactical Command Platforms - Tactical Flag Command Center (TFCC)	Flag Data Display System (FDDS)	Receipt of OSP for Tactical Comand and Control use
Cruise missile surface ships	Tomahawk Weapons Control System (TWCS)	Receipt of MDU and OSP for cruise missile targeting
Cruise missile submarines	Combat Control System (CCS)	Receipt of MDU and TOSP for cruise missile targeting

operational backup for these primary sites. It is located in Washington, D.C. The TMPC TDP goes by the title Mission Data Distribution System (MDDS). The MDDS has three primary functions which are:

1. To generate Mission Data Updates (MDU) for mobile platforms carrying land attack cruise missiles.

2. To generate Operator to Operator Notices (OPNOTE) for other user systems.

3. To receive OPNOTEs from other user systems.

[Ref. 7: p. 3-5]

Data generated by TMPC MDDS for delivery by TADIXS are sent to supporting TGF platforms for distribution to assigned shore, surface, and subsurface platforms which may either be inside or outside of the immediate satellite coverage area of the TMPC. It should be noted here that subsurface platforms receive there data's distribution in accordance with braodcast schedules established through coordination with their respective Submarine Operating Authorities (SUBOPAUTH). [Ref. 7: p. 3-5]

b. Fleet Ocean Surveillance Center/Facility (FOSIC/FOSIF)

All five FOSIC/FOSIFs are integrated into the worldwide TADIXS network located in Norfolk, Va; London, UK; Rota, Spain; Kamisea, Japan; and Makalapa, Hawaii. Each uses the Ocean Surveillance Information System (OSIS) as its TDP. A FOSIC/FOSIF TDP performs the following functions:

1. Generates event-by-event Ocean Surveillance Product (OSP) required by the mobile cruise missile platforms in order to program anti-surface ship attack missions and possible over-water land attack missions.

2. Generates OPNOTEs for other user systems.

3. Receives OPNOTEs from other systems for possible action.

4. Receives various tactical surveillance reports from mobile platforms for processing or forwarding.

[Ref. 7: p. 3-5]

These FOSIC/FOSIFs may use any methods available to them to route their messages as well as the TADIXS capabilities provided. Data generated by FOSIC/FOSIF TDPs for delivery by TADIXS are sent to supporting TGFs for further distribution to designated shore sites, surface, and subsurface platforms both with n and beyond the FOSIC/FOSIFs satellite footprint. Once again, distribution to subsurface units is performed in accordance with their respective SUBOPAUTH's broadcast schedule. Included in this is the routing of teletype messages to the SUBOPAUTH Shore Targeting Terminal (STT), a topic that will now be dealt with further. [Ref. 7: p. 3-5]

c. SUBOPAUTH Shore Targeting Terminal (STT)

There are four STTs that are integrated in the worldwide TADIXS network. They are located at Commander Submarine Forces Atlantic and Pacific (COMSUBLANT and CMSUBPAC) and at Commander Submarine Groups Seven and Eight (COMSUBGRU SEVEN and COMSUBGRU EIGHT). The TDP employed by the SUBOPAUTHs is the Tactical Data Display System or TDDS. These TDDS are designed to:

1. receive OSPs generated by FOSIC/FOSIFs destined for subsurface units. Here the TDDS performs the tailoring operation on received OSP in order to produce Tailored Ocean Surveillance Products (TOSP). This operation, performed by the SUBOPAUTH, can involve editing, coordinating other TOSP transmissions, or grouping geographically the data involved.

2. receive OPNOTEs from other user systems.

3. generate TOSPs for subsurface units.

4. generate OPNOTEs for other user systems.

[Ref. 7: p. 3-6]

A SUBOPAUTH can opt to transmit the generated TOSP over the TADIXS net or via the SSIXS. If the TADIXS is used, it is sent to the supporting TGF for further distribution to the addressed shore sites, surface and subsurface units within and/or beyond the STTs satellite footprint. [Ref. 7: p. 3-6]

2. Tactical Command and Surface Ship Launch Platforms

The Tactical Flag Command Center or TFCC, used by the Officer in Tactical Command (OTC), uses the Flag Data Display System (FDDS) as its TDP to perform the processing and display functions required by OTH-T data. Here OTCIXS and TADIXS link controllers interface with the FDDS to support receipt of the OTH-T data via the respective OTCIXS and TADIXS satellite channels, and transmission of OTH-T data via the OTCIXS satellite channels. In addition the FDDS:

a. receives MDUs generated by the TMPC MDDS.

b. receives OSPs generated by the FOSIC/FOSIF OSIS processor.

c. receiver OPNOTEs generated by other user systems.

d. generates OPNOTEs for other user systems.

[Ref. 7: p. 3-6]

The Tomahawk Weapon Control System (TWCS) is the TDP that interfaces the cruise missile surface ships with the OTCIXS and TADIXS satellite channels in order to receive OT-T data and transmit OTH-T data on the OTCIXS channel. The TWCS also:

a. receives MDU generated by the TMPC MDDS.

b. receives OSP generated by the FOSIC/FOSIF OSIS processor.

c. receives OPNOTEs generated by other user systems.

d. generates OPNOTEs for other user systems.

[Ref. 7: p. 3-6]

3. Submarine Launch Platforms

The TDP that interfaces with OTCIXS and TADIXS link controllers on cruise missile capable submarines is the Combat Control System (CCS). Additionally, the CCS accomplishes multi-source interfaces by way of the Sensor Interface Unit (SIU). With an SIU, TADIXS, OTCIXS, and SSIXS link controllers can receive OTH-T data by way of their respective channels, and transmit OTH-T data on OTCIXS and SSIXS channels. The CCS also:

a. receives MDU generated by the TPMC MDDS.

b. receives TOSP generated by the STT TDDS.

c. receives OPNOTEs generated by other user system.

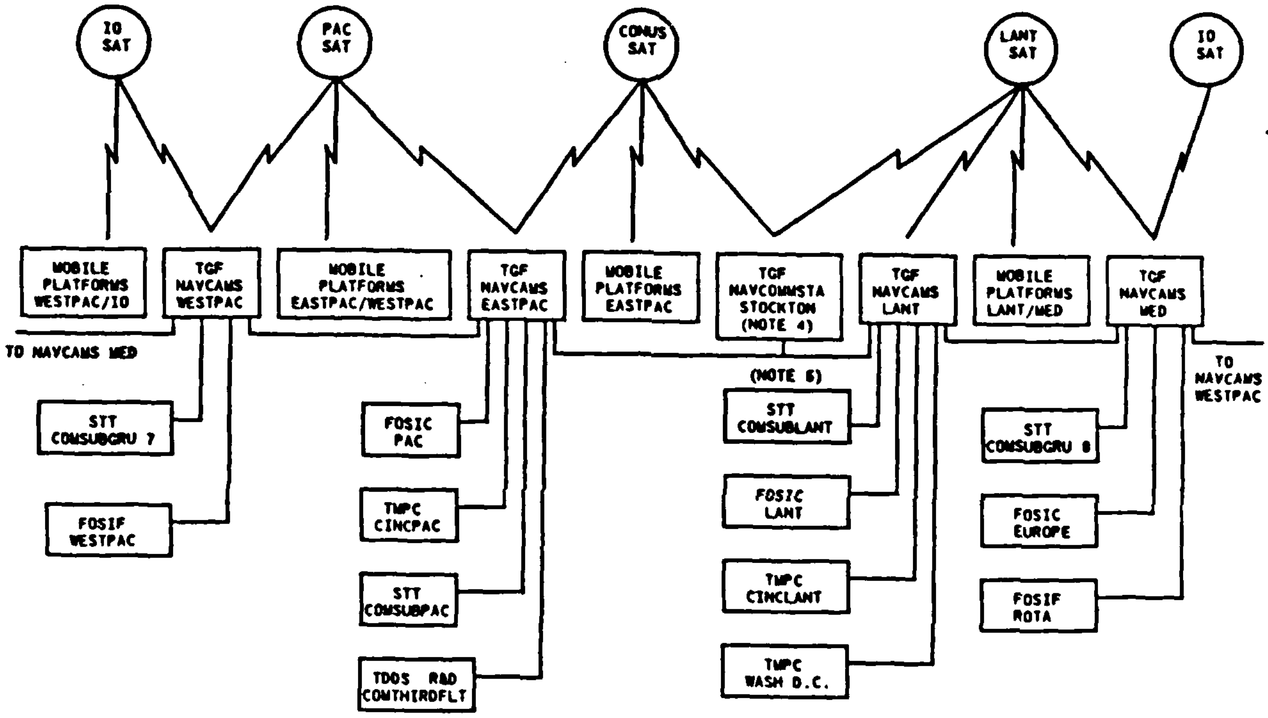
d. generates OPNOTEs for other user systems.

[Ref. 7: p. 3-7]

F. CONNECTIVITY

The connectivity between end users and their systems is accomplished using both satellite links and landlines. Landlines are used to provide local area connectivity betweeen TDP shore sites and their local TGFs, and between local TGFs where possible. Where hardwired landlines are not feasible, satellite links are used. Figure 3-2 is provided to help envision the networks, both OTCIXS and TADIXS, worldwide connectivity as well as the placement of the user systems and platforms discussed in this section. [Ref. 7: p. 3-9]

As discussed in Chapter I, satellite links are provided by the Navy's FLTSAT and LEASAT programs. The choice of either of these satellites is transparent to the TADIXS user. There will be both DAMA and Non-DAMA TADIXS circuits employed until the entire fleet is equipped for UHF DAMA. Presently one DAMA slot is provided in each coverage area providing shore-to-ship connectivity for the DAMA equipped subscribers as well as one UHF channel in each satellite footprint allowing Non-DAMA circuit users to provide shore-to-ship connectivity.



NOTES:
1. ALL SATELLITE LINKS SHOWN REPRESENT BOTH TADIXS AND OTCIXS CHANNELS
2. TADIXS TWO-WAY INTERACTIVE BETWEEN TCFs WHEN USED FOR INTER-AREA RELAY - RECEIVE ONLY TO MOBILE PLATFORMS
3. OTCIXS TWO-WAY INTERACTIVE ON ALL LINKS
4. NAVCOMMSTA STOCKTON IS A BACK-UP FOR NAVCAMS EASTPAC
5. CONNECTIVITY BETWEEN NAVCAMS EASTPAC AND NAVCAMS LANT MAY BE VIA NAVCOMMSTA STOCKTON

Figure 3-2 OTCIXS/TADIXS Worldwide Connectivity [Ref. 7: p. 3-8]

G. CONCLUSION

This chapter has discussed TADIXS concept of operation both in the operational (transmission procedures) and administrative (manipulation of data by ship and shore platforms) sense. Often included in these discussions (both Chapters II and III) were the roles of satellite relays that are the crucial part in the successful operation of these networks. It is now time to explore the operation, advantages, and disadvantages to the MILSTAR system.

IV. THE MILITARY STRATEGIC AND TACTICAL RELAY SYSTEM (MILSTAR)

A. OVERVIEW

MILSTAR will be a satellite constellation consisting of satellites in both geosynchronous and geostationary inclined circular orbits, which will maximize world coverage to include the polar regions. The system uses its own standard waveform to access the satellite which also improves its anti-jam (AJ) and Low Probability of Intercept (LPI) capabilities. A high emphasis must be placed on MILSTAR's survivability features of Electromagnetic Pulse (EMP) hardening, onboard processing, and crosslinking, the latter two of which tradeoff into transmission delays. MILSTAR is designed to be used by 2400 bps data rate or less, high priority users.

This chapter provides a primer on the operation of the MILSTAR system. MILSTAR's various capabilities and modes of operation will be explored which will lead us into Chapter V where a discussion on under what circumstances transitioning OTCIXS/TADIXS subsystems might occur. The "MILSTAR/FEP and NESP Terminal," written by Nathan Liskov of the Navy Ocean Systems Command (NOSC) [Ref. 9], is the source of all facts, figures, and operational explanations in the remainder of this chapter except where otherwise noted.

B. THE MISSION

The Military Strategic and Tactical Relay System (MILSTAR) is being designed to provide essential strategic and tactical communication services for Army, Navy, and Air Force terminals in both peacetime and wartime. MILSTAR has been designed to be more survivable due to its improved EMP protection, also known as hardening, its ability to crosslink to other satellites in its constellation, and the satellite's independent maneuvering capability. (See Figure 4-1)

C. CONCEPT OF OPERATION

The standard MILSTAR waveform has been designed to provide multi-point communications while providing protection against uplink and downlink jamming as well as against an adversary locating a platform by way of its radiated energy. The uplink signal uses an Extra High Frequency (EHF) carrier while downlinking in the Super High Frequency (SHF) bandwidth.

MILSTAR anti-jamming (AJ) and low probability for intercept (LPI) features are the result of transmitting in a very large bandwidth (2 GHz uplink/1 GHz downlink) to hide a relatively small amount of information (from 75 to 2400 bps) and by taking advantage of operating within a narrow antenna bandwidth.

MILSTAR CONFIGURATION

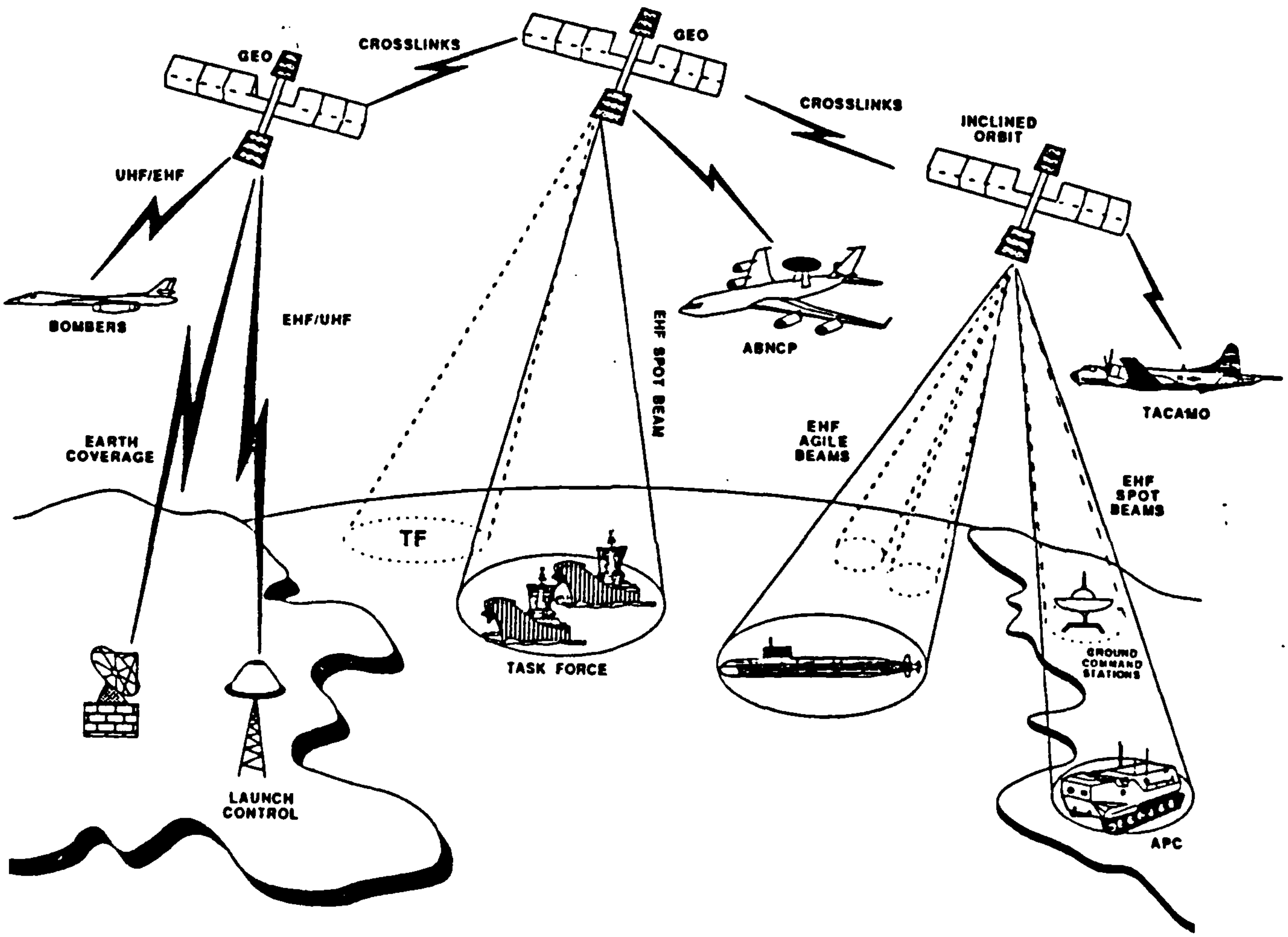


Figure 4-1 MILSTAR Configuration

Bandwidth spreading is accomplished by breaking up the signal into short time frames and sending each frame at a pseudorandom frequency within an allocated total bandwidth. This process is known as frequency hopping. The receiver dehops the recovered signal because it is time synchronized with the transmitter and uses a synchronized "random" frequency pattern to decipher it. A jammer or interceptor would not know this "random" or hopped pattern of the transmitted signal, thus making it difficult to decipher by possibly assuming the information being sent is spread across the entire antenna bandwidth.

MILSTAR has both a Low Hop Rate (LHR) and a High Hop Rate (HHR) capability. Additionally, narrow antenna bandwidths on both uplinks and downlinks provide protection against jamming.

MILSTAR is designed to provide survivable communications. It is designed for distributed control over communication services thus denying the inherent vulnerability risked by a centrally controlled system.

In order for MILSTAR to function dynamically the system has been subdivided into three segments: space, terminal, and control. Each will be discussed separately.

D. THE SPACE SEGMENT

Satellite antennas are designed to perform different functions. Tradeoffs among these designs normally revolve around the amount of gain they provide versus their amount of earth coverage and/or data rates. Whatever the antenna, a terminal must be in a satellite's beam coverage in order to access its uplink/downlink signal. Following is a list and description of the three classifications of antennas MILSTAR will possess.

1. Earth Coverage Antenna

This antenna's beam covers the view of the earth as seen by the satellite from a synchronous altitude (22,300 miles). In order to provide coverage of the entire earth with earth coverage satellites, four satellies would have to be placed on an equatorial plane as well as some in polar orbits.

2. Spot Beam Antennas

These antennas are more versatile in that they can be commanded to point in a desired direction. This might be used to cover a specific geographic area so as to provide communication services to, say, a Navy task force. As the present operatng plans suggest, two 1.7 degree spot beams will be assigned to Navy task forces and a medium spot beam assigned to Army Ground Mobile Forces (GMF).

3. Agile Beam Antennas

An agile beam antenna is an array of fixed antenna beams covering the earth as seen by the satellite. This allows for quick electronic switching among beams so that each frequency hop of data can be directed to a different beam in the array. This process is known as beam hopping. For instance, a terminal not covered by a spot beam may use an agile beam to link. A major advantage to agile beams is that each beam has more gain than an earth coverage beam thus providing a better link. A disadvantage is that these beams may suffer the effects of an orbital yaw caused by either satellite motion, terminal motion, or earth rotation. Terminals using agile beams must account for this as necesary by changing to a beam with the best coverage at any given time. The functional agile beams and the remaining antennas MILSTAR will employ are listed and described as follows. There will be one of each described antenna per satellite except where noted.

a. Downlink Agile Beam Antenna

This antenna is used to transmit data hops to terminals operatng in the agile beam downlink.

b. Agile Beam Acquisition Antenna

This antenna is used to provide uplink satellite acquisition functions for terminals desiring agile beam communication services on the CINCNET or tactical agile beam antennas. It has a secondary function of providing an uplink orderwire signaling channel to be discussed later.

c. The CINCNET Agile Beam

This agile beam will be used to receive uplink data hops from strategic users that cannot be served by a spot beam. As its name implies, this beam is used to support all strategic CINCNET network functions.

d. Tactical Agile Beam Antennas (HHR/LHR)

The tactical agile beams, of which there will be six, are used to receive uplink data from tactical users that must operate in an agile beam antenna. The HHR tactical agile beam will be assigned to Navy ship and/or Army GMF terminals while the LHR antenna will be assigned to the Navy in support of its submarine force and other terminals that use LHR. Tactical agile uplink beams only support point-to-point calls and limited access to multipoint networks. In effect this means that one uplink user per satellite is allowed with this antenna.

e. Reportback Agile Beam Antennas

This is used to provide earth coverage uplink reportback service for Navy submarines and Air Force bombers.

f. UHF Fleet Broadcast Antenna

The UHF Fleet Broadcast is sent over this antenna. A downlink data signal similar to that used in previous generations of UHF satellites is used; however, the uplink signal is sent in EHF. The MILSTAR satellite provides the necessary cross-banding (See Figure 4-2) to UHF. SHF downlinks of FLTBDCST can also be provided if need be.

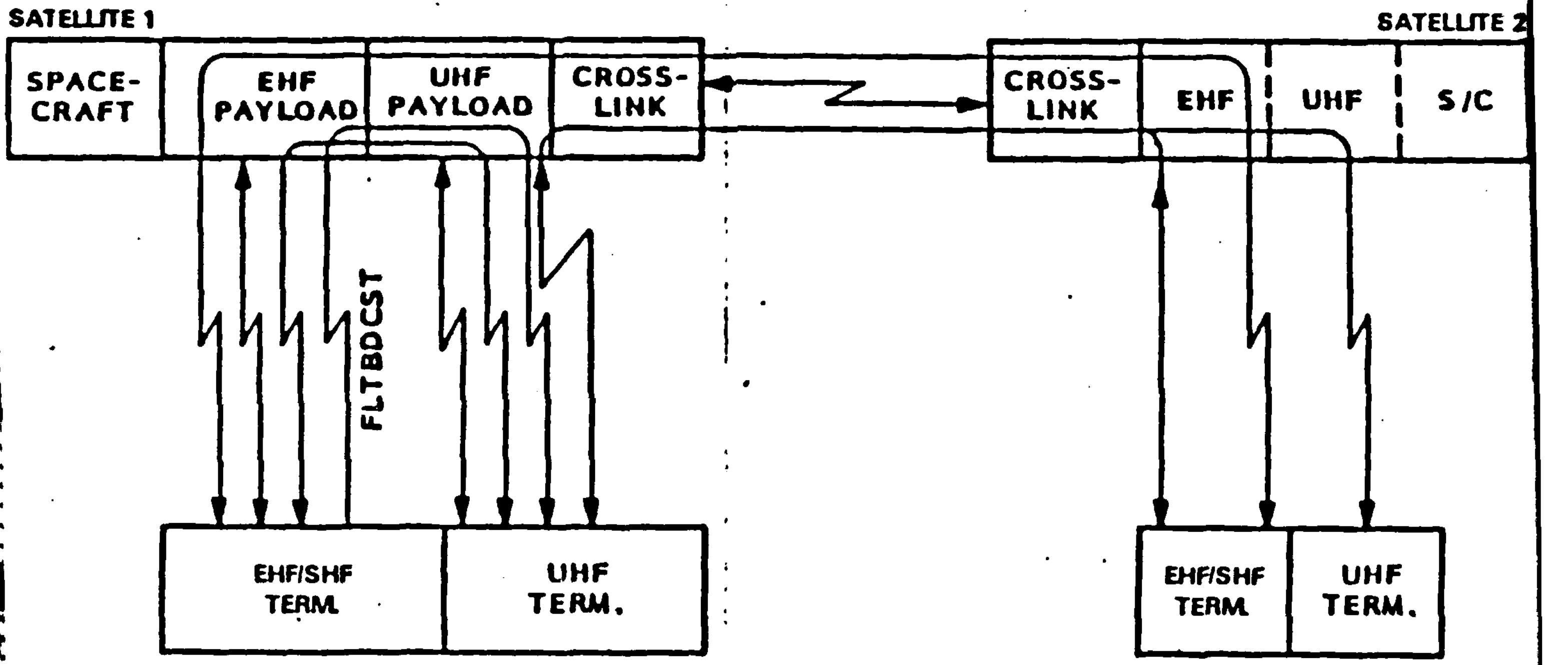
g. The UHF AFSAT Antenna

This antenna will support Air Force UHF signals. Additionally it will support crossbanding from EHF to UHF for Emergency Action Messages (EAMs) and Force Direction communications.

h. Crosslink Antennas

MILSTAR is the first satellite system to employ this technique. Crosslinking to other satellites is a survivability feature that will maintain worldwide connectivity, re-routing messages in the event a satellite or ground station is destroyed or degraded somewhere in the constellation.

MILSTAR is a processing instead of a signaling satellite. A signaling satellite is one that in essence acts like a mirror, retransmitting a signal back to earth. MILSTAR's processing capabilities allow for communications connectivity between terminals operating in different antenna beams. A transmitting terminal can send its data into one antenna and a set of downlink data hops can be sent to each downlink beam containing users participating in that service. In short, MILSTAR nets can include users who are operating in earth coverage beams, spot beams, and agile beams in one or more satellite footprints. Terminal communications and the circuits they employ drive the use of these antennas.



- CROSSLINKING OF THE EHF AND UHF
- CROSBANDING EHF TO UHF AND UHF TO SHF
- UHF TO UHF
- EHF TO SHF

Figure 4-2 Crossbanding Functions

The most important function residing in the space segment lies in the satellite's ability to perform antenna reconfigurations. Reconfiguration is the ability to transmit messages and/or user coverage from, say, the earth coverage antenna to the spot or agile beam antennas on either the same or a different satellite, which requires crosslinking. This reconfiguring process improves MILSTAR's survivability beyond all previous satellite systems, but it also causes MILSTAR's primary drawback, that of transmission delays due to reconfiguration processing.

E. THE TERMINAL AND CONTROL SEGMENTS

Circuit networks used by the MILSTAR terminals can all be set up, used as necessary, and taken down when a mission is complete by terminal controlelrs. They may be multi-user networks or point-to-point calls. The Navy has selected the Navy EHF Satellite Program (NESP) terminal for its control setment.

The MILSTAR Control Segment (MCS) consists of the equipment, support facilities, and management functions to control the satellite. The MCS consists of the following subsegments:

--MILSTAR Control Center (MCC)

--MILSTAR Master Control Center (MMCC)

--Constellation Control Center (CCC)

--MILSTAR Control Element (MCE)

--Joint Communications SATCEN (JCSC)

Further elaboration and detail on the control subsegments must be preempted due to security considerations. However, the following is a summary of MILSTAR ship/shore terminal communciation capabilities.

1. Primary/Secondary Communications

Primary channels (CO Channels) provide a more robust communication link than the secondary (Cl) channels. There are four primary transmit/receive channels providing 75-2400 bps capacity and four secondary transmit/receive channels providing 75-300 bps capacity. These capabilities will be elaborated on later.

2. Receive-only Communications

There are four receive-only channels providing 75-300 bps capacity.

3. Signaling Orderwires

These channels are used to setup, modify, or disestablish communication circuits. Protocols are used which may be initiated by the terminal operator at the Terminal Control Unit (TCU) keyboard. Protocols can be initiated by th terminal itself, a satellite resource controller on board the satellite, or other terminals in the system. What is called the uplink C2 signaling orderwire is assigned to the terminal after uplink acquisition is completed. The terminal then has access to three C3/Acquisition Reportback OrderWires (AROW) assigned to its ndetwork. These C3/AROW channels are each at different levels of link robustness with corresponding data rates, i.e., the stronger the channel the higher the data rate. The terminal normally uses the channel with the highest data rate C3/AROW it is able to receive. C2 channels are individually assigned to each terminal in the circuit while the C3/AROW are time shared among the active terminals in the net.

In MILSTAR the reportback agile beam is used for reportback uplink data transmission and the C3/AROW for acknowledgement. The satellite will gather all uplink reportback messages and then format them into a single data stream for downlink to the involved terminals by way of what is called a 'bundled' downlink data stream.

F. SATELLITE TERMINAL INTERFACES

1. Antenna Interfaces

As previously mentioned, satellite terminals may operate in a variety of uplink/downlink antenna combinations. The agile downlink beam is always used with the earth coverage (EC) uplink beam. Here the terminal may operate in a receive-only mode where the uplink is not connected. Downlink acquisition is done on the downlink beam on which the terminal will operate. Uplink acquisiton occurs on the uplink beam on which the terminal will operate. Each satellite uplink antenna can support only one frequency hopping rate (LHR or HHR) at a time. The terminal can only operate an HHR uplink into beams configured for them. However, the downlink can support both HHR and LHR signals but only on a time shared basis. Furthermore, if a terminal is operating in a HHR mode it is able to receive both HHR and LHR signals. If it is set up for LHR then it can only receive LHR downlink signals.

2. Signal Interface

Each satelite uplink antenna receiver groups its channels by way of a Frequency Division Multiple Accessing (FDMA) scheme (See Figure 4-3). These channels are hopped according to a random hopping pattern. A given frequency channel may be dedicated to a unique uplink function such as performing the uplink acquisition, or the channel may be time shared. These uplinks are designed such that a terminal can only send one hopped frequency at a time, although the processing MILSTAR satellite can receive hopped frequencies intended for different frequency channels within the receiver group at each antenna.

The satellite downlink uses a Time Division Multiple Accessing (TDMA) scheme at a single frequency which is also randomly hopped. The end result of all this is to allow the satellite to transmit and the terminal to receive at most one hopped frequency at a time. Figure 4-3 illustrates the FDMA involved with uplinking and the end result of the conversion to a TDMA downlink. Uplinked data is repeated on

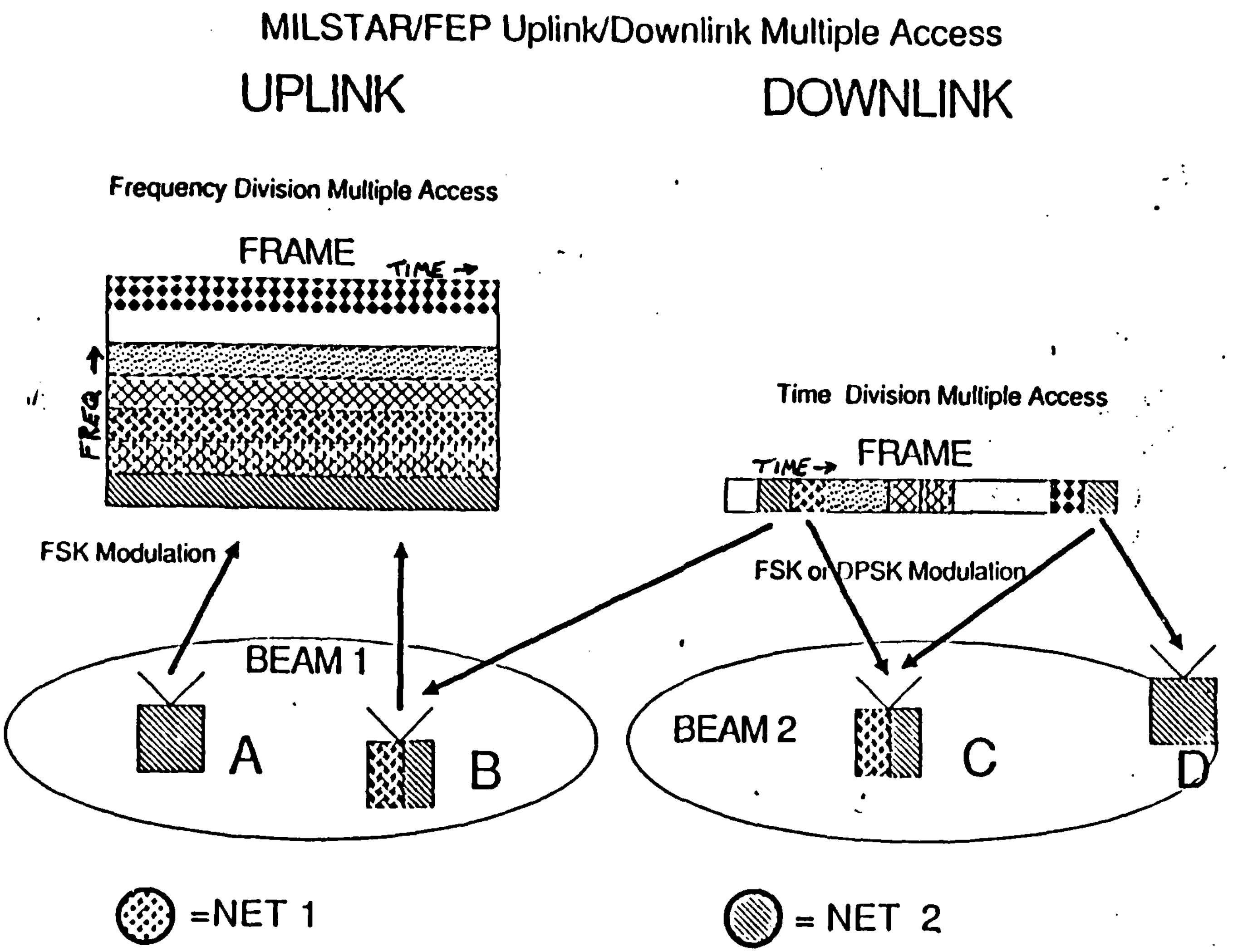


Figure 4-3 MILSTAR/FEP Uplink/Downlink Multiple Access

the downlink side to each downlink beam that contains participating terminals. This signal interface scheme allows for the following types of signals between terminals and the satellite:

-HHR Primary Communications Channels (Transmit/Receive)

-HHR Secondary Communications Channels (Transmit/Receive)

-LHR Communications Channesl (Transmit/Receive)

-Receive-Only Channels

-Uplink C2 Orderwire Signaling Channels

-Downlink C3/AROW Orderwire Signaling Channels

-Uplink Reportback Probing and Data Channels

-Downlink Synchronization Signals

-Uplink Acquisition Channels

-Uplink Time Tracking Channels

a. Primary/Secondary Communications Channels

The primary, secondary, LHR and receive-only channels cover the main terminal commuication interfaces The primary (C) channels four supports 75-2400 bps loads while secondary (C1) channels can support loads from 75-300 bps per channel. Satellites allow terminals to send up to primary and four secondary channel signals simultaneously though sending only one random frequency hop pattern within the given TDMA frame (See Figure 4-4). Primary channels provide the better uplink due to their capability to provide from 8 to 32 times more frequency hops for the same data rate if used alone.

Time Division Access Modes Allowed Within Frequency Division Access Channels

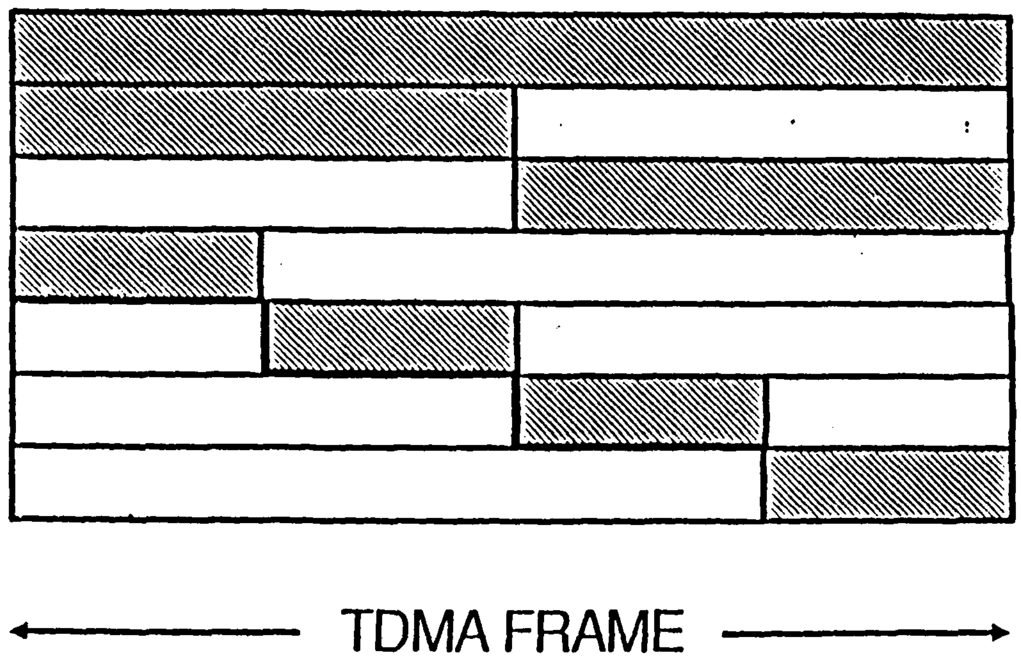


Figure 4-4 TDMA Modes Allowed Within Frequency Division Access Channels

At Low Hop Rates (LHRs), the system provides up to four simultaneous communication channels of 75-300 bps each. Each primary and secondary channel is capable of transmitting and receiving (full and half-duplex) allowing for use as a transmit-only, receive only or transmit/receive by a given user. Receive only channels may be at HHR or LHR if terminals are operating in the HHR mode. If the receive terminal is in te LHR mode it can only receive LHR signals.

b. C2 Channels

C2 uplink signaling orderwires are used to send messages tothe satellite resource controller that contains the necessary protocols to maintain communications services and system housekeeping. Each terminal is assigned its own C2 channel by the resource controller upon uplink acquisition. At HHR, the C2 transmission can be performed simultaneously with primary/secondary traffic without interference. At HHR in an emergency TTY mode and at LHR, transmission of C2 messages will interfere with primary/secondary communications. Terminal operators need to consider this when initiating protocols.

c. C3/AROW Channels

The C3/AROW downlink signaling orderwires are used to receive messages from the satellite. C3 messages originate in the satellite resource controller while AROW messages originate in either the acquisition processor in the satelite or in the reportback processor also in the satellite. AROW messages originating in the acquisition processor are called acquisition probing response messages while the reportback processor originates reportback probing responses and reportback message responses. There are three levels of robustness to their data streams with higher data rates providing lower robustness and vice-versa. Security considerations prevent their publication here.

d. Reportback Channels

Uplink reportback probing and data channels are provided in MILSTAR to perform reportback functions. The reportback agile antenna and the associated reportback channels serve both the strategic Air Force bomber and Navy submarine reportback requirements with the Navy having priority in the event of any scheduling conflicts. Reportback probing is performed prior to sending reportback messages. A satellite upon receipt of the probe sends an AROW message acknowledgement to the terminal via C3/AROW channels scheduling the agile beam to service that terminal at the proper time and frequency.

e. Downlink Synchronization Channels

This signal consists of sync hops that are sent to all the SHF beams in the downlink on a regular basis. These sync hops do not contain data but are modulated with a known timing pattern. At HHR there are both coarse and fine sync hops while at LHR there are only the coarse hops. Fine sync hops provide a precise timing pattern used by terminals operating at HHR in order to achieve the accurate timing needed to receive downlink data hops. These downlink sync hops provide the means for terminals to acquire and maintain the timing necessary to receive satellite transmissions. It performs this by time tracking, frequency tracking and conical scanning antenna tracking the sync hops.

f. Uplink Acquisition Channels

These channels are aids to the terminal in aligning its transmit timing to synchronize with the satellite's receive timing. The satellite keeps the master clock while the terminal sends timing probes through an uplink acquisition channel. The satellite calculates whether the probe arrived early or late with respect to the master clock and sends early/late responses to the terminal for adjustments via its AROW downlink channel.

g. Uplink Time Tracking Channels

These channels are used for the terminal to maintain uplink time synchronization with the satellite receive time. A terminal sends fine timing probes in its tracking channel where the satellite then measures probe arrival time responding with either an early/late time tracking response back to the terminal on the C3 channel.

At HHR the time tracking function can be performed without disrupting the primary and secondary communciations traffic. In emergency TTY mode at HHR or LHR the time tracking reduces to a repeat uplink acquisition thus disrupting all uplink communication channels.

G. MILSTAR NETWORKS AND PROCESSING CONFIGURATIONS

1. Network Support

MILSTAR has three generic transmission processing configurations, they are; single beam, single satellite, or multiple satellite configurations. These configurations will support the following types of networks:

-Point-to-point

-Fleet Broadcast

-Intra Task Force

-Inter Task Force

-Submarine Broadcast

-Reportback

Depending on the mission being supported, some services such as point-to-point calls may have a rather short duration. Services such as intra task force operations may be of considerably longer duration while Fleet Broadcasts and Reportback will exist permanently.

a. Point-to-Point

Point-to-point (PTP) connectivity provides service between two terminals either of which may be in any MILSTAR satellite beam. The two terminals can be in any spot beam, the earth coverage beam, or in any of the agile beams in either the same or different footprints. Additionally, PTP calls may be used for either data or voice depending on data rate and baseband equipment.

PTP calls will normally be set up in a half duplex mode though full duplex is possible. Once established, PTP half duplex services will operate much asit does now in its UHF environment. However, there will be some additional delay on MILSTAR caused by the satellite processing which occurs from the time that the user presses the push-to-talk button and the time the trasmission is allowed, plus the time it takes the satellite to process which uplink beam is to receive and which downlink beam is to transmit.
Here full duplex calls have an advantage by already possessing a full time transmit and full time receive channel, thus bypassing satellite antenna processing reconfigurations. However, in doing this, full duplex absorbs twice the satellite uplink and downlink resources as the half duplex process.

b. Fleet Broadcast

The Fleet Broadcast is a multipoint network possessing a single transmit terminal transmitting fleet broadcast information to many terminals over a wide geographic area.

In MILSTAR, the Fleet Broadcast transmitting terminal may be in any beam of any MILSTAR satellite and the receiving terminals may be in any UHF Fleet Broadcast beam in any satellite as well as any SHF beam in any satellite. The Fleet Broadcast uplink may be routed via crosslinks to multiple satellites and sent down the UHF Fleet Broadcast antenna in each satellite where it can be received by any terminal possessing existing UHF Fleet Broadcast reception equipment.

c. Intra Task Force

The intra task force network is a multipoint network wherein all terminals are in the same task force spot beam. Since all users are in the same beam, the network will not require any satellite reconfiguring.

The network may be used for data or voice and is operated in the same manner as a UHF multipoint network using half duplex operations. Once a network is established, the circuit discipline for sharing the channel must be performed by the end users as is done now.

A single spot beam intra task force network can be configured for TDMA. With the appropriate baseband equipment subsystems such as OTCIXS and TADIXS will be used over this net.

d. Inter Task Force

The inter task force network merely extends the intra task force mode of operating by including terminals one or more other satellite beams. An example of this might be a COMMSTA terminal operating in earth coverage or agile beams and/or terminals in a second task force spot beam. Nets like these can be used for coordination between task forces in different spot beams or for a command and control link.

e. Submarine Broadcast

This broadcast has one transmitting terminal in an earth coverage, spot, or agile beam and one receiving submarine terminal in a spot or agile beam in MILSTAR. A submarine operating in a tactical communications mode can place a PTP call to its designated command terminal requesting its broadcast data.

f. Report Network

This network is of special importance providing the facility for strategic submarines to inject reportback mesages which are returned to one or more command centers. The facility on the uplink side is designed to serve the submarine uplink reportback function. The satellite bundles together the uplink reportback messages routing them through one or more downlink beams in one or more satellites. The downlink side of the network looks like a broadcast network with the exception that each satellite is the originator of the bundled data stream.

2. The Single Uplink Beam Forced Time Slot (SUB/FS)

Transmission delay is of major concern to the OTCIXS/TADIXS community. In terms of delay the ideal network satellite configuration, regardless of the type of network being supported, is called the Single Uplink Beam Forced Time Slot or SUB/FS. It is a single beam, single satelliteconfiguration. The SUB/FS allows users to set up the network and transmit data in the same slot, meaning the same uplink modulation (Beam) type is used for every transmitting user, thus eliminating the necessity of changing the satellite's receiving mode (i.e., reconfiguring). Quick turn arounds between transmitting users can occur and reconfiguration protocols, along with their subsequent processing delays, will not occur.

Users of MILSTAR must be satisfied with the realization that their messages have a guaranteed delivery to their destinations. The tradeoff for the "guarantee" comes in the form of transmission delay, which may range from anywhere around a half of a second to, say, half an hour.

The SUB/FS scheme is limited to networks where all users are covered by a single antenna beam. Nets possessing members under multiple beams or satellites can and will incur long user-to-user turn around times due to the reconfiguration processing required for linkage among these multiple beams and satellites. With delay such an important consideration to those in the OTCXS/TADIXS community, it is now time to consider under what circumstances these subsystems might transition to MILSTAR.

V. ANALYSIS AND RECOMMENDATIONS

A. TRANSITION CONSIDERATIONS

This thesis has discussed the mission and operational concepts of th OTCIXS, TADIXS, and MILSTAR. In discussing the advantages and disadvantages of transitioning to MILSTAR the first and foremost point to be made is that MILSTAR's primary role is as a survivable strategic communication system. Tactical communication subsystems such as OTCIXS and TADIXS will not be given high priorities in hostile environments. According to a Naval Ocean Systems Command document, "The logical use of MILSTAR is as an alternate survivable (communication) service, rather than a one-for-one replacement (of UHF capabilities), augmenting the other information (exchange subsystems) and tactical data nets." [Ref. 10: p. 10] In short, MILSTAR should not be considered a replacement to the present UHF SATCOM system but as an occasional augmentation to it.

The UHF SATCOM system is the peacetime Navy SATCOM workhorse. With this in mind, it is recommended that transitioning to MILSTAR assets should be considered in the event of platform jamming, if unreasonable delays occur in the handling of important messages as a result of UHF system saturation, or finally for routine training purposes in order to familiarize personnel but which would not normally use MILSTAR, and on platforms possessing MILSTAR terminals, with proper operating procedures.

Initial Operational Capability (IOC) has already been achieved for OTCIXS/TADIXS using the Navy Fleetwide UHF Satellite System. As MILSTAR approaches IOC there will be a number of operational tradeoffs or considerations that must be taken into account in transitioning subsystems from the UHF system to MILSTAR. MILSTAR can guarantee message delivery but, to summarize, if/when a decision to use MILSTAR occurs, there will be two main effects on the operational capabilities of these subsystems to consider. They are:

1. Limited wide area coverage for OTCIXS/TADIXS cannot be supported due to the nautical mile radius constraint of the agile beam coverage. Connectivity of out-of-spot coverage ships will depend on available resources for agile beam downlinks.

2. MILSTAR will significantly increase time delays related to current protocol controls. As Task Forces or mobile platforms traverse the oceans and skyways, satellite coverage beams will have to reconfigure to maintain their coverage of these platforms. This can incur extremely long processing delays to connectivity and message handling, possibly up to a half hour. [Ref. 10:. p. 22]

MILSTAR provides worldwide connectivity but at the cost of an increase in network overhead which is a result of the reconfiguration processing function. The net operating in the Single Uplink Beam Forced Time Slot (SUB/FS) mode discussed in Chapter IV is the most efficient way to use

MILSTAR resources and keep transmission delays to a minimum. Again this SUB/FS scheme is limited to networks where all subscribers are covered by a single antenna beam. Nets possessing members under multiple beams or satellites can and will incur long user-to-user turnaround times due to the reconfiguration processing required for linkage among these multiple beams and satellites. [Ref. 10: p. 5]

- MILSTAR area coverage is limited to the area covered by any particular MILSTAR antenna being used on that area. However, the larger the coverage area, the lower the antenna gain. Each MILSTAR satellite can support two different task force spot coverage areas. These nets will normally be limited to uplink coverage with a single antenna beam area. Again a network that uses multiple uplink beam areas will have a very high processing overhead, thus leading to delays.

B. FUTURE PROBLEMS

As the IOC of MILSTAR edges closer, the issues of transitioning to or making limited use of MILSTAR will be of more consequence to those users of Navy subsystems. Certainly the future will hold many problems either remaining to be resolved or as yet unforeseen, for instance, deciding who has operational control, SUBOPAUTHs or Task or Battle Group Commanders. Operating tactics for OTCIXS and TADIXS equipped forces are presently very much in the development phase and, even without considering MILSTAR, are wide open topics for further research.

This thesis has concerned itself with present and arising technical management issues associated with subsystem transition to MILSTAR. The MILSTAR Project Office and those contracted to test and integrate the various MILSTAR components will be dealing more immediately with the problems of protocol improvement, i.e., the decrease in transmission delays, but it appears that this problem of delay caused by satellite processing and antenna reconfigurations will remain, a long range one with which and will require management attention.

APPENDIX

GLOSSARY

AJ	Anti-Jam
AROW	Acquisition and Reportback Orderwire
CCS	Combat Control System
CINCNET	Commander in Chief Net
CPU	Central Processing Unit
CUDIXS	Common User Digital Information Exchange Subsystem
DAMA	Demand Assigned Multiple Access
DART	Dynamically Adaptive Receiver Transmitter
EHF	Extremely High Frequency
EMCON	Emission Control
EMP	Electromagnetic Pulse
FBS	Fleet Broadcast System
FDDS	Flag Data Display System
FDMA	Frequency Division Multiple Access
FEP	Fleet EHF Program
FOSIC/FOSIF	Fleet Ocean Surveillance Intelligence Center/Facility
FLTBCST	Fleet Broadcast
FLTSATCOM	Fleet Satellite Communications
GMF	Ground Mobile Forces
HF	High Frequency
HHR	High Hop Rate
IOC	Initial Operational Capability
LEASAT	Leased Satellite
LHR	Low Hop Rate
LOS	Line-of-Sight
LPI	Low Probability of Intercept
MARISAT	Maritime Satellite
MCS	Mission Control Segment
MDDS	Mission Data Distribution System
MDU	Mission Data Updates

MILSTAR	Military Strategic and Tactical Relay
NAVCAMS	Naval Communications Area Master Station
NAVCOMMSTA	Naval Communications Station
NAVMACS	Naval Modulated Automated Communications Subsystem
NCS	Net Control Station
NESP	Navy EHF Satellite Program
NOSC	Navy Ocean Systems Center
OPNOTE	Operational Note
OSIS	Ocean Surveillance Information System
OSP	Ocean Surveillance Product
OTC	Officer in Tactical Command
OTCIXS	Officer in Tactical Command Information Exchange Subsystem
OTH-T	Over-the-Horizon Targeting
OTH/DC&T	Over-the-Horizon/Detection Classification and Targeting
PTP	Point to Point
ROM	Read Only Memory
SECVOX	Secure Voice
SHF	Super High Frequency
SID	Subscriber Identification Number
SIU	Sensor Interface Unit
SSIXS	Submarine Satellite Information Exchange Subsystem
SUB/FS	Single Uplink Beam Forced Time Slot
SUBOPAUTH	Submarine Operating Authority
SIT	Shore Targeting Terminal
TACINTEL	Tactical Intelligence Subsystem
TADIXS	Tactical Data Information Exchange Subsystem
TCU	Terminal Control Unit
TDDS	Tactical Data Display System
TDMA	Time Division Multiple Access
TDP	Tactical Data Processor
TFCC	Tactical Flag Command Center

TGF	Tactical Gateway Facility/TADIXS Gateway Facility
TMPC	Theatre Mission Planning Center
TOSP	Tailored Ocean Surveillance Product
TTY	Teletype
TWCS	Tomahawk Weapons Control System
UHF	Ultra High Frequency
VOCODER	Voice Operated Coder

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