Chapter 11

U.S. SATELLITE COMMUNICATIONS SYSTEMS

Instantaneous worldwide communications, connecting all nations, has been a dream of mankind for ages. Until the development of technologies to build, launch and operate artificial earth satellites, specifically communications satellites, the means to make such connections was unavailable. Through communications satellites, it is now possible to access telephone, telegraph, instant news information and computer links around the globe. This global connectivity provides military commanders with the ability to exercise nearly on-scene command and control. Communication satellite systems and uses continue to develop rapidly.

HISTORY

One of the most remarkable prophecies of the twentieth century was published in the magazine *Wireless World* in 1945. In a short article, "*Extra-Terrestrial Relays,*" British scientist and fiction writer Arthur C. Clarke described the use of, in 24-hour orbits positioned above the world's land masses, to provide global communications (**Fig. 11-1**).

Clarke stated:

> *"An artificial satellite at the correct distance from the earth could make one revolution every 24 hours, i.e., it would remain stationary above the same spot and would be within optical range of nearly half of the earth's surface. Three repeater stations, 120 degrees apart in the correct orbit, could give television and microwave coverage to the entire planet."*

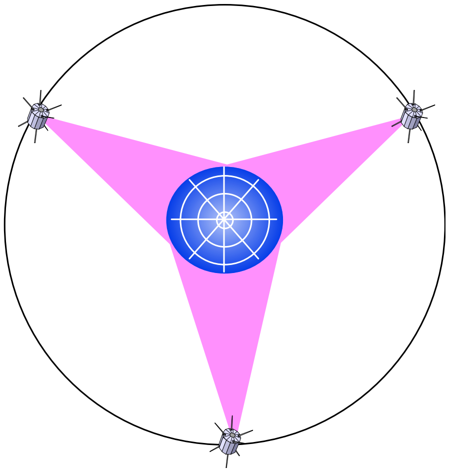


Fig. 11-1. Clarke Orbit

Clarke's theory made little impact until John R. Pierce of AT&T's Bell Laboratories evaluated the various technical options and financial prospects of satellite communications. In a 1954 speech followed by an article published in 1955, Pierce, unaware of Clarke's article 10 years earlier, elaborated on the utility of communications "mirrors" in space: a medium-orbit "repeater" and a 24-hour orbit "repeater." Pierce compared the communications capacity of a satellite, estimated to be 1,000 simultaneous telephone calls, and the communications capacity of the first transatlantic telephone cable (TAT-1), which could carry 36 simultaneous telephone calls. Since the cable cost $30-50 million, Pierce wondered if a satellite would be worth a billion dollars.

Communications by Moon Relay

The U.S. Navy began conducting experiments in 1954 bouncing radio signals off of the moon. These experiments led to the world's first operational space communications system, called Communication by Moon Relay (CMR) (**Fig. 11-2**), The relay was used between 1959 and 1963 to link Hawaii and Washington, DC.

In 1957, the Soviet Union launched the world's first artificial satellite, Sputnik I. This sparked great interest and speculation, as many began to consider

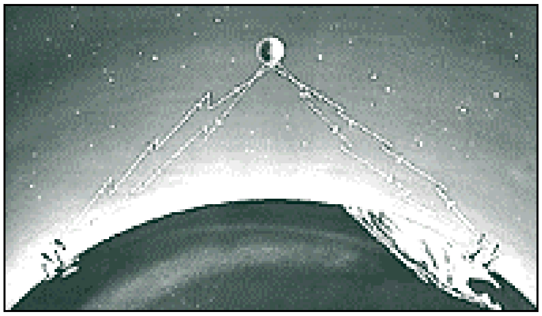


Fig. 11-2. Communications by Moon Relay

the benefits, profits and prestige associated with satellite communications.

In the late 1950's and early 1960's, NASA began experimenting with passive (reflector) communications satellites such as Project Echo. About the same time, the Department of Defense, with ADVENT program, worked to develop active (or "repeater") satellites that amplify the received signal at the satellite.

NASA launched Echo 1 on 12 August 1960 (**Fig. 11-3**). Leonard Jaffe, the director of the communications program NASA Headquarters, wrote:

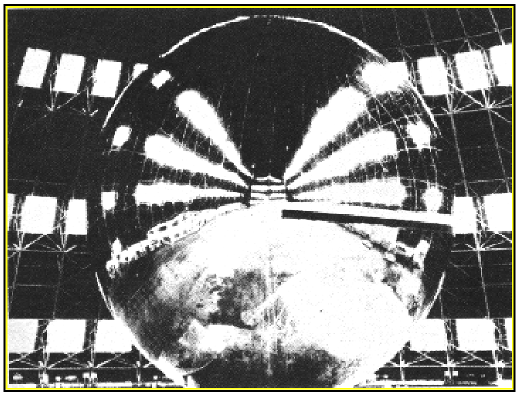


Fig. 11-3. Echo I Satellite

"Numerous experiments were conducted with Echo I in the early months involving practically all of the types of communications. Echo I not only proved that microwave transmission to and from satellites in space was understood and there would be no surprises but it dramatically demonstrated the promise of communications satellites. The success of Echo I had more to do with the motivations of following communications satellite research than any other single event."

The Echo I spacecraft was a 100-ft. diameter balloon made of aluminized polyester. It was inflated after being put into a 800-900 nautical mile orbit. Radio waves could be reflected off of the smooth aluminum surface.

Echo demonstrated satellite tracking and ground station technology that would later be used in active systems. After Echo II was launched on 25 January 1964, NASA abandoned passive communications systems in favor of the superior performance of active satellites.

In 1961, three active satellite programs were started under contract to and with cooperation of NASA. Two were for medium-orbit satellites and one for a 24-hour-orbit "repeater." The programs culminated in the 1962 launch of two medium-orbit satellites, TELSTAR and RELAY, and the 1963 launch of SYNCOM, the first 24-hour orbit (geostationary) satellite.

Meanwhile, the military program to build a geostationary satellite (ADVENT) was experiencing delays in launcher availability and cost over-runs. Therefore, and also in light of the complexity of the satellite, the program was canceled.

The first operational military satellite communications system began five years later and was comprised of two Initial Defense Communications Satellite Program (IDSCP) satellites, which were launched in July 1967. These satellites were designed to launch in groups of up to eight, and a total of 26 IDSCP satellites were launched in four groups to near geostationary, 18,300 statute mile orbits. The IDSCP evolved into what is today's Defense Satellite Communications System (DSCS). The IDSCP satellites are often referred to as DSCS Phase I.

In February 1969, the IDSCP was followed by the Tactical Satellite Communications (TACSATCOM) program. This program was used to evaluate mobile user needs in tactical situations. One

TACSATCOM satellite was placed in geostationary orbit to support the Tactical Communications Program. The TACSATCOM would become the Fleet Satellite Communications (FLTSATCOM) Program.

CURRENT OVERVIEW

Continuous global coverage from a medium altitude satellite orbit (200-10,000 NM above the earth) would require from 18 to 24 satellites. Full global coverage between 70° North latitude and 70° South latitude can theoretically be achieved using three equally spaced (120° apart) geostationary satellites. Operationally, four or more satellites are required to provide this coverage in order to mitigate the effects of a satellite failure on our networks. Four satellites provide overlapping capabilities, greater traffic handling capacity and a measure of redundancy.

Satellite systems have significantly improved the reliability and the accuracy of aviation and maritime communications, moving those functions out of the high frequency (HF) portion of the radio spectrum. The advantages of satellite communications are extensive. Although submarine cables, fiber optics and microwave radio can effectively compete with satellites for geographically fixed wide-band service, the satellite is unchallenged in the provision of wide-band transmissions to mobile terminals. The inherent flexibility that a satellite communications system provides is essential to the conduct of military operations both nationally and globally. There no viable alternatives to satellite communications for military applications.

Military Satellite Communications (MILSATCOM) comprises three primary systems (all in geosynchronous orbits), operating in three specific frequency regimes as follows:

- The Fleet Satellite Communications System (FLTSATCOM), consisting of the Fleet Satellites (FLTSAT) and UHF Follow-on (UHF F/O) satellites, operate in the Ultra-high Frequency (UHF) spectrum at 225 - 400 MHz.
- The Defense Satellite Communications System (DSCS) operates in the Super-high Frequency (SHF) spectrum at 7250 - 8400 MHz.
- The third system, Milstar, operates mainly in the Extremely-high Frequency (EHF) spectrum at 22 - 44 GHz.

Each of the three systems above provide support for a fourth system, the Air Force Satellite Communications system (AFSATCOM). AFSATCOM is not a system of dedicated satellites, but a system of dedicated channels or transponder packages riding on the satellites of the MILSATCOM system. AFSATCOM is used to disseminate Emergency Action Messages (EAMs) and Single Integrated Operations Plan (SIOP) information.

The 50th Space Wing, located at Schriever AFB, Colorado, controls DSCS and Milstar, through the 3rd and 4th Space Operations Squadrons (3SOPS, 4SOPS), respectively. Control of the UFO and FLTSAT constellations transferred from 3SOPS to the Navy's Satellite Operations Center (NAVSOC), Pt. Mugu CA, in mid 1999. The responsibilities of 3SOPS, 4SOPS and NAVSOC for satellite control include commanding on-board satellite systems, providing tracking data for orbit determination and conducting telemetry analysis. The operators also provide trend analysis and vehicle anomaly resolution. Program direction for the above communication systems is the responsibility of the agencies that manage the various communications payloads.

FLEET SATELLITE COMMUNICATIONS (FLTSATCOM)

The FLTSATCOM system provides near global operational communications for naval aircraft, ships, submarines and ground stations. It also provides communications between the National Command Authority (NCA) and the strategic nuclear forces as well as between other high-priority users. High priority users include the White House Communications Agency, reconnaissance aircraft, Air Intelligence Agency and ground forces (e.g., Special Operations Forces).

FLTSATCOM operates primarily in the UHF band, but uses SHF for the Navy's shore-based Fleet Satellite Broadcast uplink. Some of the satellites also carry EHF transponders for use with MILSTAR ground terminals. The FLTSATCOM constellation comprises four FLTSATCOM satellites (**Fig. 11-4**) located in geosynchronous orbits. The remaining FLTSATs will be retired and replaced by UHF F/O satellites (already in orbit) after the EAM dissemination and nuclear reporting mission of AFSATCOM transitions to Milstar.

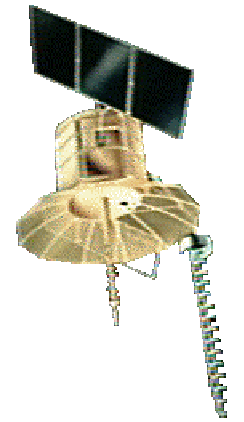


Fig. 11-4. FLTSAT

FLTSAT Mission Subsystems

FLTSAT communications packages include one SHF uplink/UHF downlink fleet broadcast channel on a 25 KHz transponder, nine 25 KHz channels, twelve 5 KHz narrow-band channels and one 500 KHz wide-band channel for use by high-priority users. Up to fourteen 25 KHz users can be accommodated on the 500 KHz wide-band channel at any one time. Antennas include UHF transmit and receive antennas, S-band omnidirectional antenna (to relay Navy SHF broadcasts) and the EHF transmit and receive antennas on Flights 7 and 8.

The U.S. Navy's NAVSOC at Pt. Mugu, CA performs Command and Control (C2) of FLTSAT and UHF F/O constellations under the Operational Control (OPCON) of Naval Space Command (NAVSPACECOM).

AIR FORCE SATELLITE COMMUNICATIONS SYSTEM (AFSATCOM)

AFSATCOM provides secure, reliable and survivable two-way global communications between the NCA and the strategic nuclear forces. The AFSATCOM system is used for EAM dissemination, JCS/CINC Internetting, CINC force direction message dissemination, force report back and other high-priority user traffic dissemination. Strategic nuclear forces include ICBM launch and control centers, B-52, B-1B and B-2 bombers and nuclear capable submarines (SSBNs). On the FLTSATCOM satellites, all twelve 5 KHz narrow-band channels and the one 500 KHz wide-band channel have been dedicated to the AFSATCOM mission. Seven of the twelve 5 KHz narrow-band channels are regenerative and can only be used for 75 BPS digital communications (not voice). The frequency range is UHF. In addition to FLTSATCOM satellites, AFSATCOM also has transponders on board other host satellites to provide coverage over the North Pole. There are two systems in use for polar coverage: the Satellite Data System (SDS) and Package D, a piggyback payload on classified host vehicles. SDS satellites include a payload similar to the twelve-channel 5 KHz system onboard the FLTSATs. However, all twelve are regenerative and can only be used for 75 BPS data. Package D satellites provide a UHF package similar to the SDS satellites. Ground control is accomplished by the host satellite network.

UHF FOLLOW-ON (UHF F/O)

The UHF F/O system consists of eight (plus one spare) satellites (**Fig. 11-5**), located in the same geosynchronous orbital positions as FLTSATCOM (two UHF F/Os at each FLTSAT location). The Navy owns the FLTSATCOM and UHF F/O systems and is responsible for the system configurations and for their communications support to all services. The main mission of UHF F/O is to support global communications to Naval forces. UHF F/O provides channels to replace the 5 KHz narrow-band channels previously available on FLTSATCOM and replaces the 500 KHz DOD wide-band channel with an appropriate number of 5 and 25 KHz channels. UHF F/O does not replace the regenerative, frequency-hopped 5 KHz channels serving the EAM dissemination and nuclear reporting mission of AFSATCOM. The Milstar system and the EHF transponders on UHF F/O fulfill these latter requirements.

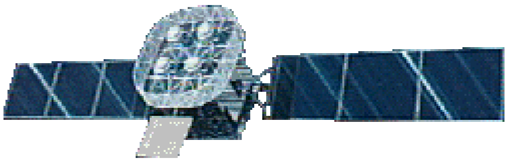


Fig. 11-5. UHF Follow-on (UHF F/O)

Each UHF F/O has 18 channels of 25 KHz bandwidth and 21 channels of 5 KHz bandwidth; essentially doubling the FLTSATCOM capability. Since there are two satellites at each orbital position, 78 UHF channels will be available over the Atlantic, Pacific and Indian Ocean regions as well as CONUS. There are no 500 KHz wide-band channels on UHF F/O. Flights four through ten have EHF transponders for use by Milstar ground terminals. Flights eight through ten also carry EHF Ka band transponders for use by the Global Broadcast Service (GBS) to broadcast missile warning, intelligence, video and imagery data to tactical units.

All UHF F/Os are Electromagnetic Pulse (EMP) protected. Although each channel can relay signals from all current military UHF SATCOM radios (those that do not require processed channels), the JCS requires all UHF SATCOM radios operate in the Demand Assigned Multiple Access (DAMA) mode unless a waiver has been granted. DAMA is a modified time sharing technique to allow more users to share the same UHF channel, 5 KHz or 25 KHz.

DEFENSE SATELLITE COMMUNICATIONS SYSTEM (DSCS*)*

The DSCS is a general-purpose satellite communications system operating in the Super-high Frequency (SHF) spectrum. The system is comprised of geosynchronous satellites, a variety of ground terminals and a control segment. It provides secure voice, teletype, television, facsimile and digital data services for the Global Command and Control System (GCCS). The system also provides communications links for management, command and control, intelligence and early warning functions.

The primary users of the DSCS are GCCS, Defense Information Systems Network (DISN), Defense Switched Network (DSN), Defense Message System (DMS), Diplomatic Telecommunications Service (DTS), Ground Mobile Forces (GMF) and the White House Communications Agency (WHCA). DSCS also supports allied nations.

Several types of ground terminals are in use. The Air Force and Navy are responsible for airborne and shipborne terminals, respectively. The strategic terminals, AN/FSC-78, AN/GSC-39 and AN/GSC-52 are maintained and operated by the Army, Air Force and Navy, depending on their location. These large terminals are equipped with 60-ft or 38-ft diameter, high-gain parabolic dish antennas, have power outputs on the order of 10,000 watts and are capable of processing thousands of voice channels. Other terminals include Tactical Satellite (TACSAT) terminals used by the Ground Mobile Forces (GMF). Owned by the Army and Marine Corps, these terminals consist of the AN/TSC-93B, with an 8 ft dish antenna, and the AN/TSC-85B with an 8 or 20 ft dish antenna. The Air Force TACSAT terminals are the AN/TSC-94A, with an 8 ft. dish antenna, and the

AN/TSC-100A, with both the 8 and 20 ft. dish antennas. The TACSAT terminals are housed in shelters that can be transported by HMMWV (TSC-93B & TSC-94A), 2 ½ ton or 5 ton truck (TSC-85B) or mobilizers (TSC-100A).

Other special user terminals controlled by the JCS include the AN/TSC-86 DSCS standard light terminal and the Jam Resistant Secure Communications (JRSC) terminal, AN/GSC-49. Both terminals are deployed with 8 as well as 20 ft dish antennas.

Some smaller terminals have only a single link capability (e.g., AN/TSC-93), whereas others are able to transmit as many as 9 links (carriers) and can receive 12 links (e.g., AN/FSC-78). The capacity of each link can vary from 1 to 96 voice circuits or digital data at rates from several kilobits per second to greater than 10 MPS. Currently, both Frequency Division Multiple Access (FDMA) and Spread Spectrum Multiple Access (SSMA) are used, with some terminals having both types of equipment. During Operation Desert Storm, over 100 TACSAT terminals were deployed to Saudi Arabia and provided more than 80% of the communications.

Each of the five operational and spare satellites has a primary and alternate network control station located at major nodes such as Ft. Detrick, Maryland.

The DSCS control segment allocates satellite capacity to best serve user requirements. Control segment computer algorithms provide an allocation process that makes use of the considerable flexibility of the DSCS III satellites. This flexibility includes the antenna patterns and connectivities and also involves precise calculations of the Effective Isotropic Radiated Power (EIRP) required to meet specified link quality. The control segment optimizes the network configuration for the FDMA, TDMA and SSMA operations. It also responds to jammers and generates command sets to configure the satellite and processes telemetry from the satellites.

DSCS Space Segment

DSCS evolved in three phases starting with the IDSCP satellites as Phase I (sometimes called DSCS I). Phase II began in 1971 with the launch of two DSCS II satellites (**Fig. 11-6**) into geostationary orbit. The third phase began in 1982 with the launch of the first DSCS III satellite.

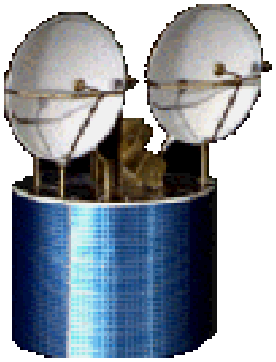


Fig. 11-6. DSCS II Satellite

The constellation today (**Fig. 11-7**) consists of five primary DSCS III satellites and five residual "spares" with limited operational capabilities. The satellites are at an altitude of approximately 22,300 miles in geostationary orbits around the equator. All ten satellites are in continuous 24-hour operations with the spares primarily used for GMF training missions.

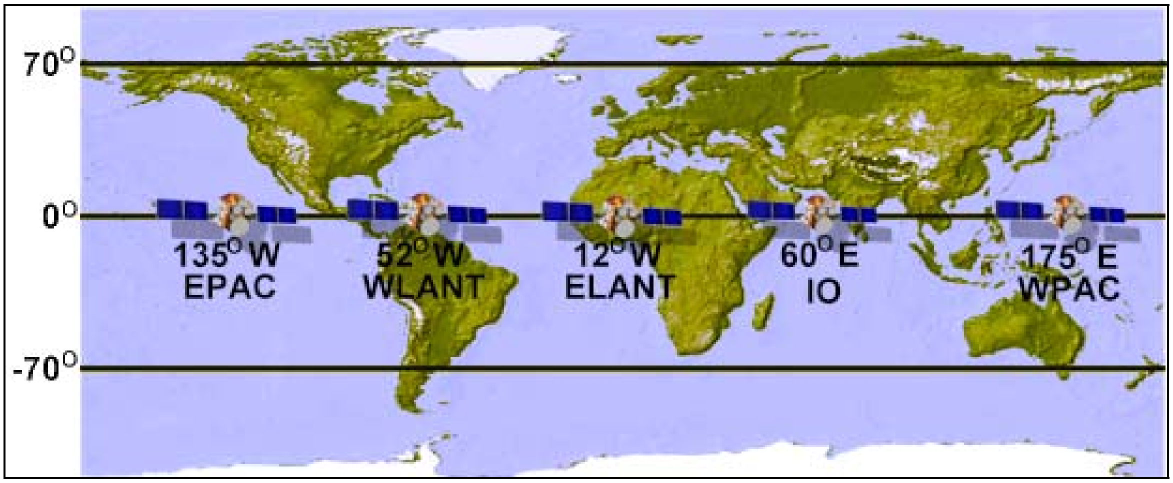


Fig. 11-7. DSCS III Notional Constellation

In addition to the DSCS III satellites, there are some DSCS II satellites (turned off) still in orbit that could be activated, on a limited basis, at any time. The DSCS II satellite located over the Indian Ocean is still active and used for training purposes.

The five primary DSCS III satellites provide overlapping footprints for worldwide communications between 70^{O} North latitude and 70^{O} South latitude. Communications beyond these latitudes becomes very weak due to earth's flattening in the vicinity of the poles. Heavy terminals, such as the FSC-78 with the large 60 foot antenna, could access a DSCS III satellite from some locations above 70^{O} North or below 70^{O} South latitude. The five satellite constellation of DSCS allows most earth terminal locations to access at least two satellites.

Key sites around the world are equipped with two earth terminals, each accessing a different satellite. These dual terminal sites allow the signal from one satellite to be retransmitted to another, extending the distance beyond one satellite's coverage area. This is called an "M-hop" (**Fig. 11-8**). M-hops make communications between opposite sides of the planet possible.

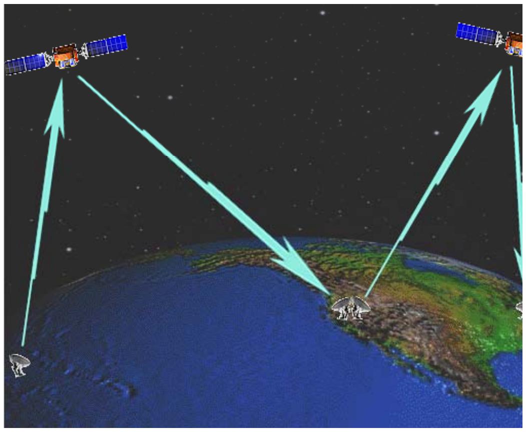


Figure 12-8. M-Hop

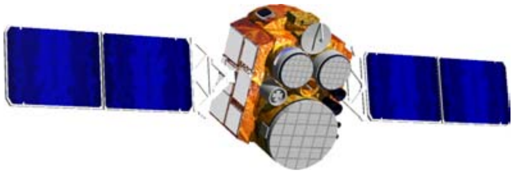


Fig. 11-9. DSCS III

DSCS III Satellite

The DSCS III spacecraft (**Fig. 11-9**) is a three-axis, momentum stabilized vehicle with an on-orbit weight of about 2,350 pounds. The spacecraft's rectangular body is 6 x 6 x 7 cubed feet, with a 38 foot span (with solar arrays deployed). The solar arrays generate 1,100 watts, decreasing to 837 watts after five years. The communications payload aboard each satellite provides a wide-band spectrum of 1000 MHz (500 MHz uplink and 500 MHz downlink) that is divided into six channels by six limited bandwidth transponders (**Table 11-1**). Four of the six channels/transponders can be switched by ground command between a number of antennas consisting of:

- Four earth coverage horns: two transmit while two receive.
- A 61-beam waveguide-lens, receive Multiple Beam Antenna (MBA) that provides selective coverage and nulling for anti-jam protection.
- Two 19-beam, waveguide-lens transmit MBAs to provide selected antenna patterns that match the network of ground receivers, and a high-gain, gimbaled dish transmit antenna for adjustable spot beam coverage.

The DSCS frequency plan falls within the SHF spectrum (X band) with uplink frequencies of 7900MHz to 8400 MHz which the transponders down-translate to the downlink frequencies of 7250 MHz to 7750 MHz. Any type of modulation or multiple access may be used since none of the transponders process or demodulate the signals.

In addition to the six wide-band SHF transponders, a Single Channel Transponder (SCT) provides secure and reliable dissemination of EAM and the SIOP communications from command post ground stations and aircraft world wide. The SCT receives communications from the ground terminals and airborne command posts at SHF or UHF, and transmits them at UHF and SHF.

Antennas	
Receive:	Two earth Coverage (EC) One Multiple Beam (MBA)
Transmit:	Two Earth Coverage (EC) Two Multiple Beam (MBA) One Gimbaled Dish (GDA)
Transponders	
Channel 1	
Bandwidth:	50 MHz
Transmitter Power:	40 W
Transmit Ant. Options:	MBA, GDA
Receive Ant. Options:	EC, MBA
Channel 2	
Bandwidth:	75 MHz
Transmitter Power:	40 W
Transmit Ant. Options:	MBA, GDA
Receive Ant. Options:	EC, MBA
Channel 3	
Bandwidth:	85 MHz
Transmitter Power:	10 W
Transmit Ant. Options:	EC, MBA
Receive Ant. Options:	EC, MBA
Channel 4	
Bandwidth:	85 MHz
Transmitter Power:	10 W
Transmit Ant. Options:	EC, MBA, GDA
Receive Ant. Options:	EC, MBA
Channel 5	
Bandwidth:	60 MHz
Transmitter Power:	10 W
Transmit Ant. Options:	EC
Receive Ant. Options:	EC
Channel 6	
Bandwidth:	60 MHz
Transmitter Power:	10 W
Transmit Ant. Options:	EC
Receive Ant. Options:	EC

Table 11-1. DSCS III Communications Subsystem

The last four DSCS III satellites are being upgraded prior to launch under the DSCS Service Life Enhancement Program (SLEP). The first two SLEP improved satellites, B8 and B11, were launched in 2000. The remaining two will launch in 2002 and 2003. Under SLEP, the solar panels are upgraded to provide more power and all of the transponders are to be upgraded to provide 50 watts of transmitted power; the channel five transmit antenna options will be changed to allow connection to the Gimbaled Dish Antenna (GDA).

DSCS Ground Segment

The ground segment consists primarily of three groups of earth terminals:

- The strategic terminals are the medium and heavy class terminal located at fixed stations
- The TACSAT terminals are used by the GMF and are deployed by the Army, Air Force and Marine Corps throughout the world
- Finally, the special user terminals are the airborne and shipborne terminals, the JRSC terminal and the JCS controlled DSCS Standard Light terminal.

The strategic terminals provide 24-hour support to both DOD and non-DOD users. These users include GCCS, DISN, DSN, DMS and the DTS.

The medium class of the strategic terminals consists of the AN/GSC-39 and AN/GSC-52. Both terminals utilize a 38 foot antenna with redundant solid-state low noise amplifiers.

The AN/GSC-39 is capable of transmitting up to 18 individual carriers and receiving as many as 30. It is equipped with two 5,000 watt transmitters that can be combined for a total output of near 10,000 watts.

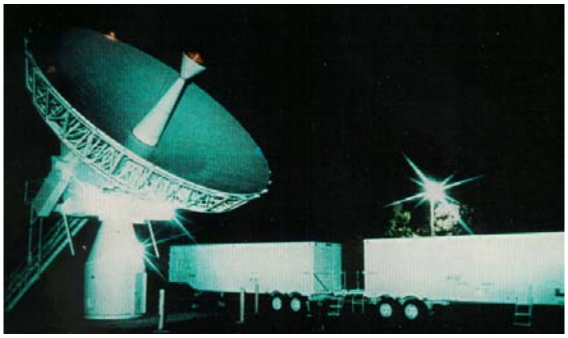


Fig. 11-10. AN/GSC-52

The AN/GSC-52, a state-of-the-art Medium Terminal (SAMT) (**Fig. 11-10**) comes equipped to transmit and receive up to 12 carriers with the ability to expand into 18. The terminal can transmit up to approximately 2,600 watts by combining the four 650 watt transmitters.

The heavy class terminal, FSC-78, is electrically the same as the GSC-39 with the exception of the antenna and low noise amplifiers. The FSC-78 is equipped with a 60–ft antenna (**Fig. 11-11**) that uses cryogenically cooled parametric amplifiers. Even though the maximum transmitter output of both terminals is the same, the maximum EIRP of the FSC-78 is far greater than that of the GSC-39 due to the increased gain of the larger antenna.

Fig. 11-11. FSC-78 60-ft Antenna

DSCS Ground Mobile Forces (GMF)

GMF operate in their own sub-network on the DSCS satellites. The GMF sub-network is not operationally compatible with the DSCS networks. This is due to the incompatibility of the GMF TACSAT terminal's signal processing equipment with that of the DSCS strategic terminal. In order for the GMF to gain access to the DSCS network, a DSCS Gateway terminal must be used.

A DSCS Gateway terminal is a strategic terminal with a complement of signal processing equipment used by the TACSAT terminals. The signal from the GMF network is processed to its lowest form by this equipment and then reprocessed by the DSCS signal processing equipment for retransmission in the DSCS network.

A GMF network consists of at least two TACSAT terminals, each transmitting one carrier which is received by the other. The TACSAT terminals are classified in one of two categories: Nodal or Non-nodal. Nodal terminals (AN/TSC-85B and AN/TSC-100A) have the ability to transmit one carrier and receive up to four. Non-nodal terminals (AN/TSC-93B and AN/TSC-94A) can transmit and receive only one carrier. Each carrier has the capacity of up to 96 telephone calls or 10 MPS of data. Links with more than 32 telephone circuits or a data rate greater than 3 MPS are far too difficult to support with the small 8 and 20-ft antennas and are rarely used.

There are three basic GMF network configurations. The simplest consists of two terminals, each transmitting one carrier received by the other. This is called a "Point-to-point" configuration. Any combination of Nodal or Non-nodal terminals can be used. One terminal could be a DSCS Gateway terminal, while the other two configurations are called "Hub-spoke" and "Mesh."

The Hub-spoke configuration consists of a Nodal terminal as the "Hub" and up to four "spokes" that can be Nodal, Non-nodal or DSCS Gateway terminals. In the Hub-spoke configuration, the hub terminal transmits one carrier that is received by all four spokes. In turn, each spoke transmits one carrier back to the hub.

A Mesh configuration is a combination of two or more hub-spoke configurations that are linked together. If a Nodal terminal is used as one of the spokes in a hub-spoke configuration, three additional terminals could be added as spokes to this terminal to create a mesh.

The TSC-85B is the nodal terminal used by the Army and Marine Corps. This terminal is equipped with two redundant 500-watt transmitters and equipment to transmit one and receive up to four carriers. It is deployed with either an 8 or 20-ft antenna, and is housed in a modified S-250 shelter transported on a 2 ½-ton or 5-ton truck.

The Army and Marine Corps' Non-nodal terminal is the TSC-93B, which is equipped with one 500-watt transmitter and can transmit and receive only one carrier. It is housed in a shelter transported on a HMMWV and is deployed with an 8-ft antenna.

The Air Force nodal terminal is the TSC-100A, which is similar to the TSC-85B. The TSC-100A is equipped with two higher power transmitters that can be combined for a total output power of approximately 1,800 watts. It is capable of transmitting and receiving up to four carriers and is deployed with both an 8 and 20-ft antenna. These antennas allow the TSC-100A to access two satellites simultaneously. It is housed in a modified S-280 shelter transported on mobilizers.

The TSC-94A is the Air Force's Non-nodal terminal which is equipped much like the TSC-93B, except for the two 500-watt transmitters and other equipment redundancy. It also deploys with only the 8-ft antenna and is housed in a shelter transported on a HMMWV.

DSCS Control Segment

The Chairman, Joint Chiefs of Staff has primary responsibility for DSCS with USCINCSPACE having Satellite Operations Manager (SOM) responsibilities as defined in CJCSI 6250.01. The Defense Information Systems Agency (DISA) is the DSCS SATCOM System Expert (SSE), and network manager, and executes DSCS command and control in support of the Global and Regional SATCOM Support Centers (GSSC, RSSC). DISA is a DOD agency that reports directly to the Chairman of Joint Chiefs of Staff and the Assistant Secretary of Defense for C3I. The DISA mission is to develop, test, manage, acquire, implement, operate and maintain information systems for C4I and mission support under all conditions of peace and war. The DISA core mission areas include:

- Global Command and Control System (GCCS). An information system designed to support deliberate and crisis planning with the use of an integrated set of analytical tools and flexible data transfer capabilities. It will become the single C4I system to support the warfighter, foxhole to command post.

- Defense Information Systems Network (DISN). A program for the graceful technology evolution from the use of DOD networks and systems to the use of commodity services wherever possible. It replaces DSNET and supports DSN, SIPRNET, NIPRNET and FTS 2000 (Fed Telecomm System). DISN also provides information transport services for voice, text and imagery.
- Defense Message Service (DMS). A program geared towards reducing cost and staffing while maintaining existing levels of service and security for DOD messages. Its goal is for secure, accountable and reliable writer to reader messaging for the warfighter at reduced cost.
- Global Combat Support System (GCSS). GCSS uses GCCS as a baseline. It is a strategy to integrate existing combat support systems to gain efficiency/interoperability in supporting the warfighter. It will provide a fused, real-time combat support view of the battlespace, eliminating stove-piped systems by achieving a common operating environment (COE).

DSCS launch, on-orbit operations (station-keeping), telemetry analysis, tracking data for orbit determination and commanding of on-board subsystems is the responsibility of the 3SOPS. 3SOPS is a component of the 50th Operations Group, 50th SW at Schriever AFB, Colorado.

Under USARSPACE, the 1st Satellite Control (SATCON) Battalion mission is to provide communications network control for the DSCS. The 1st SATCON Battalion operates and maintains five DSCS Operations Centers (DSCSOCs) worldwide. The DSCSOCs provide real-time monitoring and control for the DSCS and GMF networks. They also perform payload control, which involves making changes to transponder and antenna configuration.

JCS, as specified in CJCSI 6250.01, validates all DOD and non-DOD MILSATCOM requirements, apportions resource capacity, approves satellite repositioning and resolves conflicts. USSPACECOM, for the JCS, provides operational direction along two paths.

USCINCSPACE is responsible for assuring access to, and use of, space for the U.S. and its allies and for operating Joint Staff designated space systems in support of U.S. and allied military forces.

USCINCSPACE is also the principal space advocate and advisor to the CJCS. Responsibilities include:

- Assessing the worldwide impact of proposed satellite movements
- Providing recommendations to the CJCS
- Providing a space assessment to DISA and the Joint Staff based on MILSATCOM requirements as documented in the Satellite Database (SDB).

USCINCSPACE provides operational command through its components in order to:

- Operate and maintain the Mission Control Centers (MCCs)
- Execute tracking, station-keeping and ephemeris generation
- Execute satellite movements as directed by the CJCS.

USCINCSPACE provides operational command through USARSPACE in order to:

- Operate and maintain all DSCSOCs
- Provide personnel resources to ensure network and payload control
- Operate and maintain GSSC and RSSC's and for GMFSC network planning and coordination

DISA Code DOT provides technical direction through the GSSC and RSSC's in order to:

- Direct network and payload control executed by the DSCSOCs
- Direct station keeping and movements executed by the MCCs

The RSSCs, through coordination, will:

- Obtain satellite-engineering parameters to be used for resource allocation to the GMFSC and assistance in resolving conflicts from the DISA.
- Receive and process satellite access requests from the CINCs for GMFSC access and provide satellite access authorizations.

DSCS Access

Access to the DSCS satellites is accomplished differently depending on whether the user desires the DSCS network and the GMF network. For DSCS network access, the following is a summary of the process:

1) Users identify their requirements.
2) Users submit their requirements to their respective CINC.
3) The CINC's J6 will coordinate with the GSSC, applicable RSSC and DISA for the required resources.
4) DISA will engineer the link parameters to support the requirements. The information is passed to the DSCS Ops Centers where the Network Controllers add/subtract/monitor the entire net.
5) The user is informed of the circuit design (power/bandwidth/times of usage).
6) Communication stays open between all parties to assure the warfighters' needs are met.

For GMF access, the tactical user receives mission tasking and begins the planning process with the Communications Systems Planning Element (CSPE). The CSPE determines the mission's satellite communications requirements and develops a Satellite Access Request (SAR) for the RSSC.

The SAR consists of the following:

- Who, When, What, Where and How
- Unit and Mission, date/time, data rate, terminal types and location, network configuration and priority

The RSSC will:

- Coordinate with DISA for resources to support the SAR
- Perform network planning with parameters given by DISA if the SAR can be supported.
- Develop Satellite Access Authorization (SAA) with the satellite, look angles, power, frequency and controller.

The SAA is sent to the originating CSPE, DISA and the controller. The CSPE produces deployment orders and configuration sheets for terminals while DISA directs the controlling DSCSOC to update their operational database. Finally, 30 minutes prior to the mission start time, the controller contacts the terminals and directs access to the satellite.

MILSTAR

Milstar provides highly robust, secure and survivable communications among fixed-site and mobile terminals. The name "Milstar" originated as the acronym for Military Strategic and Tactical Relay satellite system. In the early '90's the acronym was adopted as the system name, and is therefore not written in capital letters. The MILSATCOM Joint Program Office manages Milstar at the Space and Missile Systems Center, Los Angeles AFB, California.

Originally, Milstar was required to provide assured connectivity through all levels of conflict for strategic nuclear and strategic defense forces. The Milstar Low Data Rate (LDR) payload was designed to meet this requirement, and each of three Services developed LDR terminals to use the Milstar LDR payload. However, in the National Defense Authorization Act for FY91, Congress requested the DOD to restructure the Milstar system to reduce cost, increase the utility of the system to tactical users, and eliminate the most enduring nuclear warfighting capabilities. The DOD responded by reducing the number of large strategic terminals and increasing the number of smaller tactical terminals. Other changes included the elimination of the most durable nuclear survivable capabilities for satellites and terminals and the addition of a Medium Data Rate (MDR) capability on satellite 3 and beyond, to support tactical users.

Operating primarily in the Extremely High Frequency (EHF) and Super High Frequency (SHF) bands, Milstar satisfies the U.S. military's communications requirements with worldwide, anti-jam, scintillation resistant, Low Probability of Intercept (LPI) and Low Probability of Detection (LPD) communications services.

The first Milstar satellite (**Fig. 11-12**) was launched from Cape Canaveral on 7 February 1994 aboard a Titan IV booster with a Centaur upper stage. The second Milstar satellite was launched from Cape Canaveral on 6 November 1995. They are in low-inclination, geosynchronous orbits at an altitude of approximately 22,300 miles. The first two satellites are block I units with only LDR (75 to 2400 BPS) capability. Milstar flight 1 is positioned at 120° West longitude and flight 2 is positioned at 4° East longitude. The block I satellites will be replaced with an operational constellation of block II satellites having MDR (4.8 KBPS to 1.544 MBPS) payloads. Four block II vehicles were produced. However, the first Milstar II failed to reach orbit after its April 1999 launch. Three Milstar II's remain to be launched.

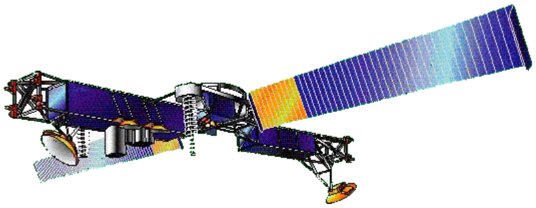


Fig. 11-12. Milstar

Like other satellite systems, Milstar is comprised of three segments, the Space Segment, Mission Control Segment and the Terminal Segment.

Space Segment

The Space segment consists of 3-axis stabilized satellites measuring approximately 51 feet in length. The 116-ft. solar arrays generate almost 8,000 watts of power. Often described as a "switchboard in the sky", the Milstar payloads have onboard computers that perform communications resource control. Milstar responds directly to service requests from user terminals without satellite operator intervention, providing point-to-point communications and network services on a priority basis. The Milstar payloads can reconfigure in real-time as user connectivity needs change. Milstar also employs satellite crosslinks to establish and maintain worldwide connectivity without having to rely on M hops. In the satellite's EHF and SHF bands, high gain transmit and receive antennas with small apertures produce narrow beams which are difficult to jam.

Mission Control Segment

The Mission Control Segment performs Milstar state of health maintenance, constellation control, satellite repositioning and communications management. A primary feature of this segment is its survivability, which derives from its combination of fixed station at Schriever AFB, Colorado and ground mobile control stations.

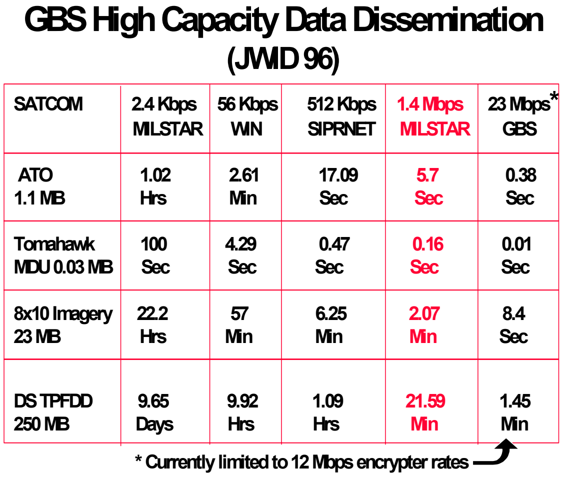
Terminal Segment

The Terminal Segment includes fixed and mobile ground terminals, ship and submarine terminals and airborne terminals. The Army, Navy and Air Force are developing and procuring terminals that are inter-operable.

The 4SOPS, a component of the 50th Operations Group, 50th Space Wing, Schriever AFB, is responsible for overall command and control of the Milstar satellite constellation. The 4SOPS executes these responsibilities through the Milstar Operations Center (MOC) at Schriever AFB, Mobile Constellation Control Stations (MCCSs) and the Milstar Support Facility (MSF). MOC personnel located in the Operations Building at Schriever AFB, perform satellite command and control, communications resource management, systems engineering support, mission planning and anomaly resolution for the Milstar system. The MOC has two fixed CCSs which interface with the geographically distributed Mobile CCSs, to execute satellite command and control. The Milstar Support Facility personnel, also located in the Operations Building, perform ground control maintenance and testing, and hardware and software configuration control.

GLOBAL BROADCAST SERVICE (GBS)

The Global Broadcast Service (GBS) is based on technology of the commercial TV industry to broadcast one-way, very large streams of data (or video) to large numbers of small receiver antennas simultaneously. The need for a worldwide, high throughput broadcast system became evident during the Gulf War. Service-owned and leased commercial communications channels were so overwhelmed that crucial information such as maps and intelligence data had to be airlifted to the warfighter. GBS was initiated as the program to fill that need. The GBS is intended to provide a large quantity of broadcast data to the warfighter, and consistently provide it in a time frame that allows the warfighter to act within the decision cycle time of the adversary. The amount of time to transmit a single Air Tasking Order (ATO) over Milstar LDR is in excess of one hour. Milstar MDR, at a full T1 data rate, requires close to 6 seconds **(Fig. 11-13).** GBS, even with the limiting factor of current encryption equipment, transmits the data in less than one half second. Additionally, because it is a broadcast stream of data, it can send to many small receivers simultaneously.



GBS High Capacity Data Dissemination
(JWID 96)

SATCOM	2.4 Kbps MILSTAR	56 Kbps WIN	512 Kbps SIPRNET	1.4 Mbps MILSTAR	23 Mbps* GBS
ATO 1.1 MB	1.02 Hrs	2.61 Min	17.09 Sec	5.7 Sec	0.38 Sec
Tomahawk MDU 0.03 MB	100 Sec	4.29 Sec	0.47 Sec	0.16 Sec	0.01 Sec
8x10 Imagery 23 MB	22.2 Hrs	57 Min	6.25 Min	2.07 Min	8.4 Sec
DS TPFDD 250 MB	9.65 Days	9.92 Hrs	1.09 Hrs	21.59 Min	1.45 Min

* Currently limited to 12 Mbps encrypter rates

Fig. 11-13 Capacity Comparison

Another unique benefit of GBS is that it can transmit to relatively small, phased array receive antennas mounted on mobile platforms. This provides the capability to send imagery or other large file products in real-time to aircraft, ships and vehicles in motion.

The GBS program leveraged Commercial Off The Shelf (COTS), Government Off The Shelf (GOTS) technology and Non-Developmental Items (NDI) to facilitate faster system acquisition and fielding. Additionally, the acquisition was divided into three phases.

GBS Phase I is a continuation of a Concept of Operations (CONOPS) testbed initially placed in service by the National Reconnaissance Office (NRO). The testbed is operated by DISA and managed by USSPACECOM. It employs a single over-CONUS leased commercial Ku band satellite transponder and is used to support operational military broadcasts, exercises and to integrate system lessons learned into GBS Phase II.

GBS Phase II establishes an interim operational capability using GBS transponder packages hosted on UHF F/O satellites 8, 9, and 10. Each of these GBS transponder packages has two 30 GHz (K band) uplink antennas and three 20.2-21.2 GHz (Ka band) downlink spot beams. Two of the spot beams provide 500 nm nadir footprints while the third provides a 2000 nm nadir footprint. **Fig. 11-14** shows representative GBS Phase II spot beam footprints. The beams can be shifted from one edge of the coverage to the opposite edge in approximately three minutes.

GBS Phase III will further evolve the capabilities of GBS beyond the 2005 timeframe.

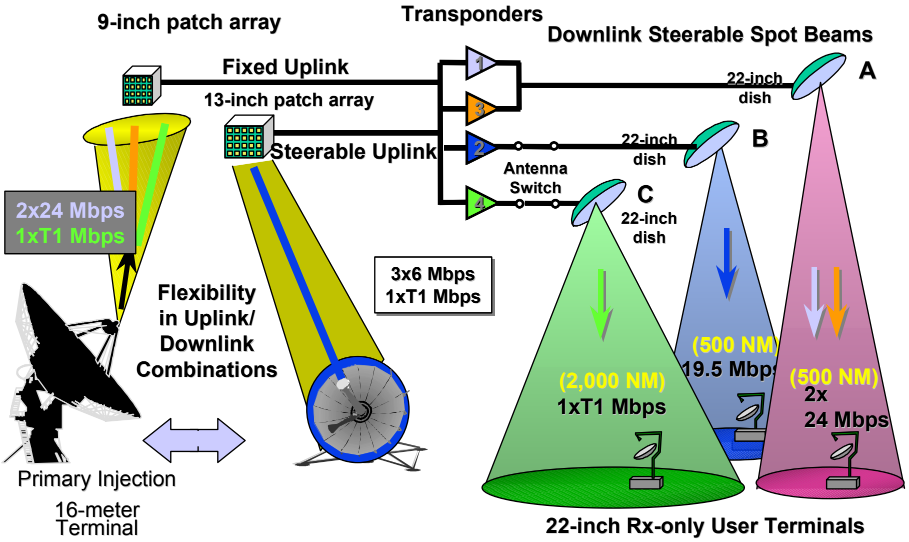


Fig.11-14 Phase II Transponder Footprint

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