

Chapter 13

WEATHER/ENVIRONMENTAL SATELLITES

Timely knowledge of weather conditions is of extreme importance in the planning and execution of military operations. Real-time night and day observations of current weather conditions provide the operational commander with greater flexibility in the use of resources for imminent or ongoing military operations. The military has firmly established the importance of meteorological data from satellites in the effective and efficient conduct of military operations. Satellite-based remote sensors provide situational awareness of environmental conditions and allow geographical access to areas that otherwise would not be directly available.

DEFENSE METEOROLOGICAL SATELLITE PROGRAM (DMSP)

segments: the Space Segment, the Control Segment and the User Segment.

Mission

Space Segment

The DMSP mission is to provide an enduring and survivable capability to collect and disseminate global visible and infrared cloud data and other specialized meteorological, oceanographic and solar-geophysical data in support of worldwide DOD operations. This service must be available through all levels of conflict.

The Space Segment consists of the expendable launch vehicle, the spacecraft (vehicle) and the individual sensor payloads. Currently, the DMSP satellite is launched on the Titan II launch vehicle from Vandenberg AFB, California. The launch weight of the satellite is 3,212 lbs., with a final on-orbit weight of 1,750 lbs (including the 520 lb sensor payload). The satellite is injected into a near circular, sun-synchronous, 450 nautical mile (NM), near-polar orbit with a period of 101.6 minutes and an inclination of 98.75 degrees. This sun-synchronous orbit is crucial for DMSP operations. The launch profile is such that the satellite crosses the Equator at the same local solar time and, consequently the same light level, each day. In this sun-synchronous orbit, the orbital plane precesses eastward at the same rate the earth orbits about the Sun (approximately one-degree per day).

DMSP was designed to provide the military with a dedicated weather observing system. Under peacetime conditions, weather data are also available from civil weather satellites, such as Geostationary Operational Environmental Satellite (GOES) and the Television InfraRed Operational Satellite (TIROS) polar orbiting satellite. The National Oceanic and Atmospheric Administration (NOAA) now operates all of these systems. While such systems provide useful information, the DMSP has specialized meteorological capabilities to meet specific military requirements. Through DMSP satellites, military weather forecasters can detect developing patterns of weather and track existing weather systems over remote areas.

The space-based portion of DMSP nominally consists of two satellites with nodal crossings of early morning and midmorning. The on-orbit satellites operational at the end of December 2000 were designated as the Block 5D-2 (**Fig. 13-1**).

The DMSP accomplishes its mission through a system of space and ground based assets categorized into three

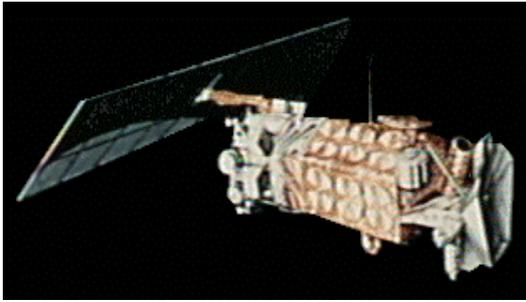


Fig. 13-1. DMSP 5D-2 Deployed

This model is the second in the Block 5D series and was first launched on 20 December 1982. This \$40 million spacecraft is a 3-axis stabilized, earth-oriented vehicle. Using a hands-off, precision attitude-control system, the spacecraft is capable of maintaining a .01 degree pointing accuracy in all three axes.

This pointing accuracy is required to avoid optical distortion in the primary sensor. The vehicle carries redundant on-board computers in both the spacecraft body and primary sensor. This redundancy has reduced the possibility of a single-point failure and increased the mean on-orbit lifetime of the spacecraft to 3-4 years.

The next version of DMSP satellites is the Block 5D-3. Block 5D-3 satellites

consist of the same major component subsystems as the Block 5D-2 satellites (Fig. 13-2). However, 5D-3 satellites have increased payload capacity, increased power capability, improved on-orbit autonomy (60 days), and a design life duration of 5 years. The first launch of a 5D-3 satellite (DMSP F-16) is scheduled for early 2001. Although DMSP F-15, launched in December 1999, featured the new 5D-3 satellite bus, it carried the legacy 5D-2 sensors. Precise launch dates depend on how long the satellites are able to remain on orbit and meet mission requirements. The 5D-3 satellites will be designated Flights 16-20.

Each satellite carries an Operational Linescan System (OLS) as the primary sensor. Up to 12 additional mission sensors can be carried on-board the satellites. The combination of the OLS and the other mission sensors results in an existing capability for the DMSP to satisfy many of the meteorological requirements of the DOD. While each of the sensors provides valuable mission data, only the OLS and the Special Sensor Microwave Imager (SSM/I) will be addressed in detail. A brief description of the other sensors will follow.

Operational Linescan System. The OLS

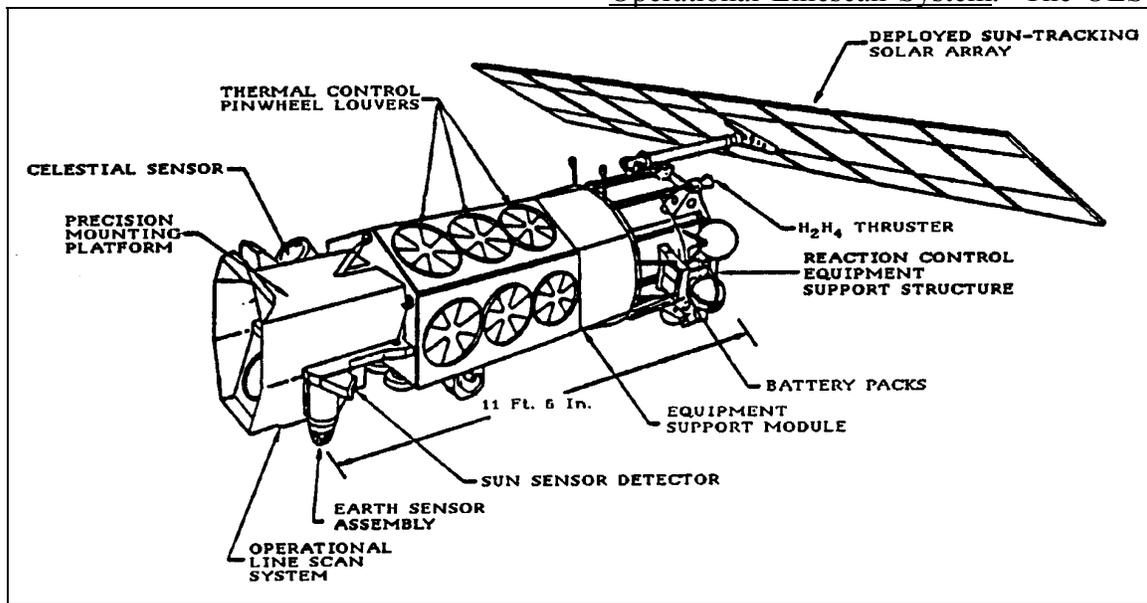


Fig. 13-2. DMSP Block 5D-2 Satellite

is the primary sensor on-board the satellite for providing visual and infrared imagery. The OLS, built by Westinghouse Corporation, is a sophisticated cloud imager consisting of an oscillating-scan radiometer and a data processor and storage system. It is designed to gather, process and output data in real-time to tactical sites, and store (on four recorders), both day (Fig. 13-3) and night visual data and infrared spectrum imagery. The recorders on 5D-3 satellites have been upgraded from digital tape recorders to a more reliable solid state design. The OLS scanning radiometer (in actuality, a Cassegrainian telescope) oscillates at six cycles per second and scans a 1,600 nautical mile-wide swath with little or no distortion at the edges.

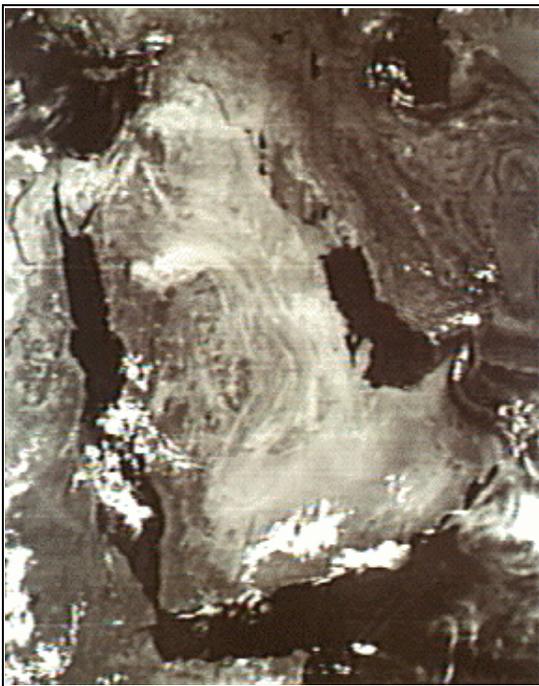


Fig. 13-3 OLS Image

Imagery collected by OLS is formatted into three data types:

- The thermal detector collects thermal fine resolution data continuously day and night.
- Light (visual) fine data is gathered during daylight only. Fine resolution data has a nominal

linear resolution of .3 nautical miles. However, satellite contact duration (typically 10 minutes) limits the vast quantity of fine resolution data, which can be stored for subsequent transmission to the ground. As a solution, the capability exists on board the spacecraft to digitally average or "smooth" the fine data into a 1.5 nautical mile resolution format.

- Data smoothing permits global coverage in both the Thermal Smooth (TS) and visual Light Smooth (LS) modes. Nighttime collection of visual imagery can be accomplished in the LS mode by using a low-resolution Photo Multiplier Tube (PMT). The PMT is effective under one-quarter or better moonlight conditions. The OLS also has the capability to combine fine-resolution data, interleaved with "smooth," for real time downlink to remote ground terminals.

The capacity for on-orbit storage of fine-resolution data for subsequent transmission to the ground is limited to 40 minutes. This is less than half of the satellite's 101 minute single-orbit period. The stored data is transmitted down to a ground station at a 4:1 ratio during a single satellite contact.

Smoothing the fine-resolution data inputs permits global coverage in a LS or TS mode. Up to 400 minutes of smoothed recorded data can be played back at a 40:1 ratio during typical ground station contact.

The OLS data management unit has a capability for acquiring, processing, recording and outputting data from up to 12 other mission sensors. One of the most significant of these sensors is the SSM/I.

Special Sensor Microwave Imager (SSM/I). The SSM/I is a seven channel, passive microwave radiometer sensing radiation at 19, 22, 37 and 85 GHz. It detects the horizontal and vertical polarizations at 19, 37 and 85 GHz. The

microwave brightness temperatures are converted to environmental parameters such as sea surface wind speeds, rain rates, cloud water, liquid water, solid moisture, ice edge and ice age. The SSM/I data are processed at centralized weather facilities and some tactical sites. The data are collected in a swath width of almost 760 NM. The resolution is 13.6 NM at the lower three frequencies and 7.8 NM at 85 GHz.

Other Sensors: Other DMSP sensors include:

- Microwave Temperature Sounder (SSM/T-1). A passive microwave sensor used to obtain radiometric measurements at seven frequencies. The data provides atmospheric temperature profiles for pressure levels between the earth's surface to 30 km.
- Microwave Water Vapor Profiler (SSM/T-2). A passive microwave sensor used to obtain water vapor mass in seven layers and relative humidity at six levels. It provides data on contrail formation as well as location of weather systems with high water vapor content with no associated clouds.
- Microwave Imager/Sounder SSMIS (Block 5D-3 only). Also a passive microwave sensor; however, it combines the capabilities of the SSM/I, SSM/T-1 and SSM/T-2 for the Block 5D-3 satellite.
- Ionospheric Plasma Drift and Scintillation Monitor (SSI/ES). A suite of four sensors that measures ion and electron temperatures, densities and plasma irregularities characterizing the high latitude space environment.
- Enhanced Ionospheric Plasma Drift and Scintillation Monitor (SSI/ES-2). This sensor is an upgrade to the SSI/ES. Data is used to support HF and UHF communications and is used for atmospheric drag calculations for low earth orbit satellites.
- Plasma Monitor System SSI/ES-3 (Block 5D-3 only). This sensor is an upgrade to the SSI/ES-2 and performs the same mission.
- Precipitating Electron and Ion Spectrometer (SSJ/4). Detects and analyzes electrons and ions that precipitate into the ionosphere producing the auroral displays. The sensor supports those missions which require knowledge of the state of the polar ionosphere such as communications, surveillance and detection systems (for example, the Over-the-Horizon (OTH) radar) that propagate energy off or through the ionosphere.
- Precipitating Particle Spectrometer SSJ/5 (Block 5D-3 only). A follow-on to the SSJ/4 with a new detector design capable of providing a greater detailed analysis of the ionosphere.
- Gamma Ray Detector (SSB/X). The SSB/X sensor is an array-based system that detects the location, intensity and spectrum of x-rays emitted from the Earth's atmosphere.
- Gamma Ray Detector (SSB/X-2). An upgraded SSB/X with the additional capability to detect gamma ray bursts.
- Triaxial Fluxgate Magnetometer (SSM). Provides information on geomagnetic fluctuations that affect HF communications.
- Ultraviolet Limb Imager (SSULI-Block 5D-3 only). Uses the ultraviolet spectrum to provide additional data for users of HF communications, satellite drag and vehicle re-entry issues and OTH radar.
- Ultraviolet Spectrographic Imager SSUSI (Block 5D-3 only). Gives the 5D-3 satellite the ability to obtain photometric observations of the nightglow and nightside aurora.
- Laser Threat Warning Sensor (SSF). An operational static earth viewing, laser threat warning sensor. Currently in prototype on the 5D-2 satellites, the operational version will fly on the 5D-3 satellites.

Control Segment

The Control Segment (**Fig. 13-4**) makes use of ground station sites that operate to command and control the DMSP satellites. These sites collect and process environmental data collected by the DMSP constellation, which is then routed, to the DMSP user community. Through its communications links, the control segment provides all functions necessary to maintain the state of health of the DMSP satellites and to recover the payload data acquired during satellite orbit. Although real-time, primary-sensor payload data are available to deployed tactical terminals worldwide, access to stored data is obtained only

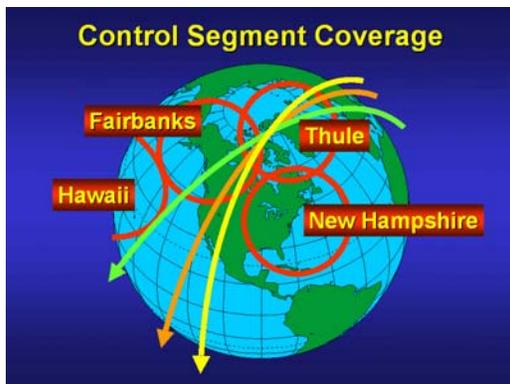


Fig. 13-4. DMSP Control Segment Coverage

when the DMSP satellite is within the Field-Of-View (FOV) of a DMSP compatible ground station.

The Multi-Purpose Satellite Operations Center (MPSOC) manned by the 6 SOPS at Offutt AFB, Nebraska (co-located with the Air Force Weather Agency), was the primary center for DMSP operations. As part of the merger of DMSP with its civilian counterpart, NOAA, the MPSOC was closed during May 1998. NOAA assumed all functions related to flying and supporting the DMSP constellation at their Satellite Operations Control Center (SOCC) at Suitland, MD on 29 May 1998. All functions to include classified mission planning were assumed by NOAA.

The 6 SOPS was then officially inactivated on 11 June 1998 as a result of the operational mission being assumed by NOAA at the SOCC. Subsequently the 6 SOPS Air Force Reserve Unit was activated at Schriever AFS and provides a “hot backup” capability for the MPSOC plus takes 10-15% of the satellite contacts per week.

The Air Force Satellite Control Network (AFSCN), using its Automated Remote Tracking Station (ARTS) can be used for routine tracking, telemetry and control (TT&C) functions. Only three (Thule ARTS, New Hampshire ARTS, and Hawaii ARTS) currently have the necessary hardware and software enhancements to retrieve DMSP mission data. Additionally the NOAA site at Fairbanks, Alaska supports DMSP data retrieval.

User Segment

While the Control Segment meets the ongoing needs of the DMSP satellites, the DMSP user community is serviced by centralized and tactical components of the User Segment. The User Segment consists of earth-based processing and communications functions required to receive, process and distribute global weather data to support Air Force, Army, Navy and Marine Corps requirements. Vans and shipboard terminals, using direct read-out of real-time infrared and visible spectrum images from the DMSP satellites, also form a part of this segment.

The Air Force Weather Agency (AFWA), the 55th Space Weather Squadron (55 SWXS) and the Fleet Numerical Meteorological and Oceanographic Center (FNMOC) are the centralized components of the User Segment. Products provided by AFWA include aviation, terminal and target forecasts; weather warnings and advisories; automated flight plans and exercise/special mission support. They recover the stored mission data from the Control Segment, process it, combine it with data from other sources (GOES, NOAA, etc.), generate weather and space environmental products and provide

operational support to their respective customers.

AFWA is the lead DOD organization for the overall processing and distribution of centralized meteorological mission sensor data in support of worldwide military activity. AFWA forwards solar-geophysical mission sensor data to the 55 SWXS, where the data will be processed and used to develop space environmental products for customers.

The FNMOC, located in Monterey, California, receives DMSP data to provide operational products and forecasts to the Department of the Navy. Specifically, FNMOC provides naval forces with analyses and forecasts of oceanographic and marine weather parameters at any global location, to include ocean surface/ocean subsurface temperatures and other meteorological conditions. AFWA and FNMOC also provide support to other elements of the DOD, the NCA and many government agencies.

The tactical components of the DMSP User Segment are the fixed and mobile land and ship-based tactical terminals operated by the Air Force, Navy and the Marine Corps. These terminals are capable of recovering direct readouts of real-time visible and IR cloud cover data from the DMSP satellites as well as SSM/I data.

Tactical terminals (TACTERMs) have been a part of DMSP since the early 1970s. These TACTERMs have the capability to receive, process, decrypt (when necessary), display and distribute the data from any DOD or NOAA meteorological satellite. They also receive localized information from the satellite, with the satellite transmitting the information it is currently observing down to the tactical user. Softcopy data (terminal display) is available real-time and hardcopy data is available within ten minutes. Imagery resolution can be both fine (0.3 NM) and smooth (1.5 NM).

The Mark IV terminal (**Fig. 13-5**) is a transportable satellite terminal designed for worldwide tactical deployment in hostile environments. Mounted in a standard shelter, the Mark IV can be

towed over virtually any terrain or transported on C-130 or larger aircraft to



Fig. 13-5, Deployed Mark IV Terminal

areas of deployment. Once deployed, it can be set up and operational within 8-10 hours.

The DMSP satellite does not constantly transmit tactical data; it must be commanded to do so. A tactical user (shipboard or land based) must make their requirements known to the AFWA. The AFWA coordinates with the NOAA Operations Center to command the satellite to transmit the tactical data during specific portions of its orbit. Not all mission sensor data is available to the tactical user, but the information from the OLS and SSM/I is available.

Another TACTERM, the Mark IV B, increases the ability to process DMSP, TIROS and GOES satellite data, allowing for processing and displaying OLS and mission sensor data by the tactical user.

The AN/SMQ-10 and AN/SMQ-11 shipboard receiving terminals are complete satellite meteorological terminals that receive, process and display real-time DMSP data. The system is designed to be used aboard aircraft carriers and designated capital ships. The SMQ-11, an upgrade to the SMQ-10, is capable of receiving full resolution DMSP OLS and SSM/I data as well as data from other civilian satellites (NOAA/TIROS).

A fully capable field system, the Small Tactical Terminal (STT) is a lightweight, two-man portable, direct receiving, processing and display system (**Fig. 13-6**). The STT processes and stores data, generates meteorological soft and hard

copy display products, and forwards imagery and data to other systems. It receives and automatically processes the DMSP Real-time Data Smooth (RDS) and Real-time Data Fine (RTD). [Note: the basic terminal is only capable of processing smooth data (RDS).]

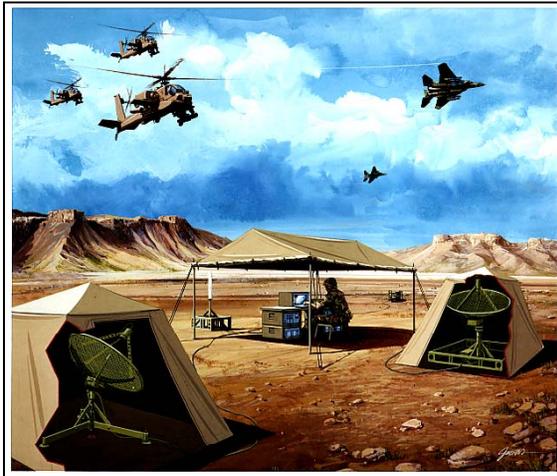


Fig. 13-6. Small Tactical Terminal Concept

The STT comes in four configurations: Basic, Enhanced, Light-Weight STT (LSTT) and the Joint Task Force Satellite Terminal (JTFST). The basic STT can be upgraded to Enhanced by adding an AN/TMQ-43 enhancement kit. The kit adds the capability to ingest, process and display RTD data from DMSP, and High Resolution Picture Transmission (HRPT) data from NOAA satellites. The new LSTT can do everything the enhanced terminal can do but uses a smaller three-foot tracking dish. The four-foot dishes will be phased out as they need maintenance by replacement with the 3-ft dish. The LSTT also has a smaller display system and can be carried in nine cases vice 12.

The STT receives data directly from the satellites in data streams consisting of visual and infrared imagery and mission sensor data. It receives and displays:

- Polar-orbiting Automatic Picture Transmission (APT) imagery (basic configuration and above).
- High Resolution Picture Transmission (HRPT) imagery. (Enhanced, LSTT, JTFST).

- Weather Facsimile (WEFAX) data (basic and above).
- High-resolution imagery transmitted by geostationary satellites (enhanced and above)

The Army primarily uses the Basic Terminal, which receives only APT and WEFAX data, while the Air Force uses the Enhanced, LSTT and JTFST terminals.

DMSP Summary

DMSP satisfies DOD's requirements for an enduring and survivable capability to collect and disseminate global visible and infrared cloud data to support worldwide DOD operations. Additionally, the DMSP collects and disseminates other specialized meteorological, terrestrial, oceanographic and solar-geophysical data. The nominal two-satellite constellation provides worldwide data in a timely manner to the AFWA, FNMOC and 55 SWXS (these are the three primary centralized processing facilities). Real time regional data are also provided to deployed fixed and transportable (ground or ship-based) tactical terminals.

DMSP and its civil counterpart, TIROS, do have one drawback - they cannot meet the data refresh rate requirements needed by all forecast functions. To partially offset this limitation, TACTERM's receive data relayed from available civilian and foreign geostationary satellites.

CIVIL/FOREIGN GEOSTATIONARY WEATHER SATELLITES

The average time it takes to get a DMSP/TIROS product to its user is 15-45 minutes depending on satellite overpass and priority of the tasking. To help offset this time delay, civilian and foreign geostationary satellites are employed. Geostationary satellite systems such as NOAA's GOES and Europe's METEOSAT offer a rapid refresh rate of cloud/weather data every 30 minutes. These satellites also offer a constant look

angle resulting in high quality “nightly news” pictures (Fig. 13-7). Spatial resolution can be as good as .5 nautical miles; however, resolution degrades the farther away you get from the nadir (center of the field of view).

Currently NOAA operates three GOES satellites over the United States:

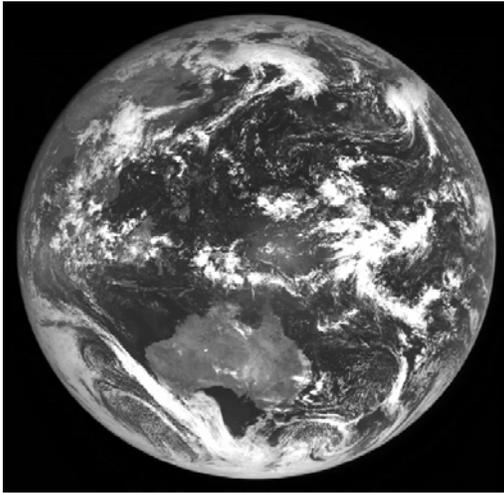


Fig. 13-7. Geostationary METEOSAT Scan

- GOES East at 75° West longitude
- GOES Central 1 spare at 105° West longitude
- GOES West at 135° West longitude

The METEOSAT, similar to GOES, covers the Atlantic Ocean/European landmass. Spatial resolution of the METEOSAT is 2.5-5 km at nadir (located at 0 degrees longitude).

Other international geostationary satellites include Japan’s Geostationary Meteorological Satellite (GMS) and the Indian National Satellite System (INSAT).

The GMS is based on an older GOES design and maintains similar capabilities. Operated by Japan, it currently has two satellites geostationed at 135° and 140° East longitude.

INSAT is operated by India and, due to it’s imaging over the Indian landmass, India has chosen not to share INSAT data with the rest of the world. However, there is an agreement in place with the Indian government that allows INSAT data to be passed to the US. INSAT also

provides a communications relay for India as a secondary mission.

On 26 June 2000, the Chinese launched a geostationary satellite, Feng Yun 2C. The Feng Yun is positioned at 105° East longitude.

The ability for weather satellites to image land masses as well as clouds has opened the door for other types of civil/commercial imaging systems that further study the world environment. Primarily designed to aid in scientific studies of the Earth’s environment, such as rain forests, desert regions, etc., environmental satellites have been used to gain wide-area imagery for military purposes.

A LOOK AHEAD

On 10 May 1994, the White House, Office of the Press Secretary, issued a Presidential Decision Directive (PDD) entitled “Convergence of U.S. Polar-orbiting Operational Environmental Satellite Systems (NPOESS).”

The satellite system that will result from that directive will be designated National Polar Orbiting Operational Environmental Satellite System (NPOESS). DMSP and TIROS have already been merged to be operated jointly by the NPOESS Integrated Program Office (IPO) and NOAA. The transition to the NPOESS is scheduled to begin by the year 2008.

NASA, as a convergence participant identified in the presidential directive, developed the TERRA Project (formally known as the Earth Observatory System (EOS) AM-1 satellite). The satellite was launched on December 18, 1999. EOS AM-1 is the first in the EOS program series. It was launched from the U.S. Air Force Western Space and Missile Center, Vandenberg AFB, into a 705 km (438 mile) sun-synchronous orbit with a morning (1030L) sun-shadow crossing time. Operational lifetime is 6 years.

The EOS AM-1 spacecraft provides detailed measurements of clouds, aerosols and the Earth’s radiative energy balance, together with measurements of the land surface and its interaction with

the atmosphere through exchanges of energy, carbon and water. These interactive processes present scientific questions of the highest priority in the understanding of global climate change.

The suite of instruments on the EOS AM-1 spacecraft is highly synergistic, and measurements from each instrument directly address the primary mission objectives. For example, four of the five instruments will acquire simultaneous complementary observations of cloud properties as well as provide error free earth surface images. All instruments together will contribute to detecting environmental changes and thereby, accelerate understanding of the total Earth system.

SUMMARY

The importance of meteorological information during a hostile conflict cannot be minimized. Environmental conditions impact all phases of military operations from logistics, to mission planning, to strike execution, to post-conflict operations. The timely and reliable relay of environmental data to military planners is critical to the success of any military operation. The DMSP provides this critical information including cloud cover data, ocean surface wind speeds, precipitation information, ocean tides information, sea ice conditions, etc.

Cloud cover data are needed to determine weather conditions in data

denied and data-sparse regions and to forecast target area weather, theater weather, en route weather (including refueling areas) and recovery weather. Surface and upper-level wind data are used to support all aspects of military operations, such as assessing radioactive fallout conditions, nuclear, biological and chemical weapon effects, movement of weather systems and predicting winds for weapons delivery. These data are required for all aspects of forecasting support to aircraft and paradrop operations.

Precipitation information (type, rate) is required to forecast soil moisture, soil trafficability, river stages and flooding conditions that could impact troop and force deployment/employment. Ocean tides information is vital to naval operations for the safe passage in and out of ports, river entrances and for the landing of amphibious craft. Sea ice conditions can have a significant impact on surface/subsurface ship operations. The location of open water areas or areas of thin ice are crucial to submarine surfacing operations, submarine missile launch and penetration by air dropped sonobuoys which are used for detecting submarines. Knowledge of the location and size of icebergs is also imperative for the safe navigation of surface ships and submarines. This information could provide an important advantage over adversaries in submarine and antisubmarine warfare.

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Current news on NOAA satellite systems from NOAA's Office of Satellite Operations.

<http://www.alcatel.com/telecom/space/observe/meteosat.htm>

Technical and operational information on Europe's "Meteosat" meteorological satellite.

<http://smis.iki.rssi.ru>

Website of the Space Monitoring Information Support Laboratory, a division of the Russian Academy of Sciences Space Research Institute. Various information and links on space objects and activities.

<http://www.ipos.noaa.gov>

Explains creation of the National Polar-Orbiting Environmental Satellite System.