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TIROS-N—Operational Environmental Satellite of the 80's

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TIROS-N, the 3rd-generation operational environmental satellite, was placed into orbit in October 1978. It is the first of eight satellites in this series that will provide service between 1978 and 1985. TIROS-N provides operational data products to the U.S. and many countries around the world. The unique design of the spacecraft permits growth for future missions. Spacecraft NOAA-E, -F, and -G in this series are being designed for ditional payload. These Advanced TIROS-N spacecraft will carry a search-and-rescue system that will permit the spacecraft to receive distress signals from downed aircraft or ships in distress, a solar backscatter uv radiometer to measure the ozone about the planet, and an Earth radiation budget experiment to measure the radiation input and loss to the planet. This paper briefly describes the TIROS-N and Advanced TIROS-N spacecraft and their operational products.

Introduction

THE TIROS satellite was orbited 20 years ago on April 1, 1960 to initiate a continuing program of polar-orbiting satellites that are serving the needs of this country and the world at large. Figure 1 depicts the TIROS evolution.

TIROS-N, the first satellite of the third-generation operational environmental satellite series, was placed into orbit October 13, 1978. NOAA-6, the second satellite in this series, was launched June 27, 1979 to complement TIROS-N. These two satellites and six additional satellites in this series will provide service between 1978 and 1985. Satellites of the TIROS-N series are in sun-synchronous, near-polar orbits. Through their multifrequency telecommunications and data handling and processing systems, they provide operational data products to the U.S. and many countries around the world.

The TIROS-N satellite system, shown in Fig. 2 (extracted from Ref. 1), provides real-time direct readout data as well as globally-stored data for playback to the primary U.S. command and data acquisition (CDA) stations. This data is used for meteorological prediction and warning, oceanographic and hydrologic service, and space environment monitoring and prediction. Spacecraft of the TIROS-N series are equipped with instruments that provide data on temperature and humidity in the Earth's atmosphere, surface temperature, cloud cover, water-ice moisture boundaries, and the proton and electron flux in the vicinity of Earth. The spacecraft's data collection system permits the reception, processing, and transmission of data from fixed and floating platforms, buoys, and balloons throughout the planet.

The unique design of the TIROS-N spacecraft permits growth for future missions. Spacecraft E, F, and G in this series are undergoing design modifications to add three additional instruments to the payload. These advanced TIROS-N spacecraft will carry a search-and-rescue system that will permit the spacecraft to receive distress signals from downed aircraft or ships in distress. The emergency signals will be relayed through a repeater system to the emergency rescue forces or will be processed onboard the satellite to indicate the location of downed aircraft and then relayed. Additional payload will consist of a solar backscatter ultraviolet radiometer to measure the ozone about the planet and an Earth radiation budget experiment to measure the radiation input and loss to the planet.

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The National Environmental Satellite Service (NESS) of NOAA operates a network of polar satellites (TIROS-N series) and geostationary satellites (GOES series) to acquire the data needed to generate the output products for which NOAA is responsible. The two satellite systems (polar and geostationary) are complementary, each uniquely qualified to meet its particular mission requirements. The TIROS-N series of satellites provides the global environmental data required by NOAA. The TIROS-N system also supports U.S. international progams by providing data for the global weather experiment and the world weather watch. Additionally, the direct readout of data from TIROS-N throughout its orbital flight permits over 800 small ground stations in 120 countries around the world to receive satellite environmental data in real time.

Spacecraft Description

Instrument Payload

The primary environmental instruments carried by the TIROS-N/NOAA satellites are as follows.

TIROS Operational Vertical Sounder

The TIROS operational vertical sounder (TOVS) is a three-instrument group consisting of: 1) the high-resolution infrared sounder (HIRS/2); 2) the stratospheric sounding unit (SSU); and 3) the microwave sounding unit (MSU). Data from TOVS provides temperature profiles of the atmosphere from sea level to 1 mbar (mb) altitude, the water vapor content at three levels of the atmosphere, and the total ozone content.

1) The high resolution infrared radiation sounder (HIRS/2) is a 20-channel instrument that measures incident radiation of the i.r. spectrum, including both longwave (15 μm) regions. The HIRS/2 has a 15 cm diam optical system to gather emitted energy from the Earth's atmosphere. The instantaneous field of view of all channels is stepped across the satellite track by use of a rotating mirror. The cross-track scan combined with the satellite's motion in orbit provides coverage of the Earth's surface during the satellite's 14.1 daily orbits. The instrument provides data that permits calculation of a) temperature profile from the surface to 10 mbar; b) water vapor content in three layers in the atmosphere; and c) total ozone content. The TOVS spatial resolution is 20 km and its temperature accuracy is approximately 1.5-2.0°C.

2) The stratospheric sounding unit (SSU) employs a selective absorption technique to make measurements in three channels. The spectral characteristics of each channel are determined by the pressure in a carbon dioxide gas cell in the optical path. The amount of carbon dioxide in the cells determines the height of the weighting function peaks in the atmosphere. The SSU pyro-electric detectors integrate the

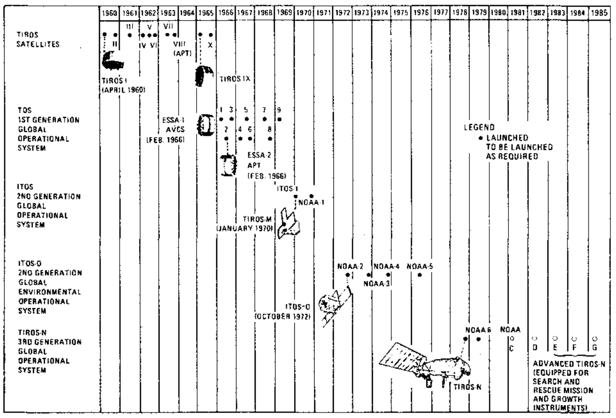

Fig. 1 **Evolution of TIROS/ITOS/NOAA meteorological satellites.**

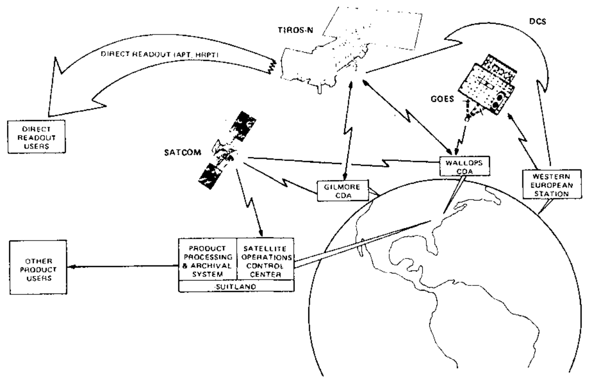

Fig. 2 **TIROS-N operational system network.**

radiance in each channel for 3.6 s during each step. The primary objective of this instrument is to obtain data from which the stratospheric (25-50 km) temperature profile can be determined. The SSU spatial resolution is 150 km.

3) The microwave sounding unit (MSU) is a 4-channel Dicke radiometer, that makes passive measurements in the 5.5-mm oxygen band. The MSU is a step-scanned spectrometer with response in the 60 GHz O_2 band and is used to produce temperature profiles in the atmosphere in the presence of clouds. The MSU spatial resolution is 110 km.

Advanced Very High Resolution Radiometer

The day and night imaging of the planet is performed by the advanced very high resolution radiometer (AVHRR), a 4-channel (5 channels on later satellites of this series) scanning radiometer sensitive in the visible, near infrared, and infrared window regions. This instrument provides data for central processing of the stored global images. The direct readout, automatic picture transmission (APT), and high-resolution picture transmission (HRPT) outputs are transmitted in real time. HRPT data (all spectral regions) is transmitted at full resolution (1.1 km); APT (two selectable spectral regions) is transmitted at reduced resolution (4 km). The present four-channel AVHRR is as follows: channel 1, 0.55-0.90 μm is used for daytime cloud and surface mapping; channel 2, 0.725-1.10 μm is for surface water delineation; and channel 3, 3.55-3.93 μm is used for sea surface temperature, day and night cloud mapping. A fifth channel to be added on future AVHRR will be 11.5 to 12.5 μm to enhance sea surface temperature measurements.

Space Environment Monitor

The space environment monitor (SEM) consists of three separate instruments and a data processing unit. This trio of instruments measures the solar proton flux, the alpha particle and electron flux density, energy spectrum, and total par-

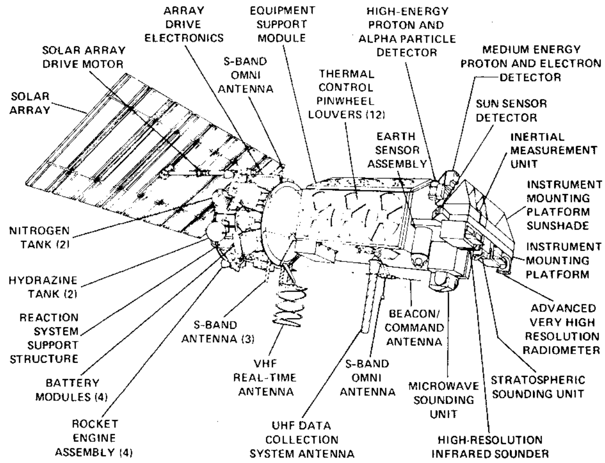

Fig. 3 **TIROS-N spacecraft.**

ticulate energy distribution at the spacecraft altitude. The instruments are: the total energy detector (TED) that measures a broad range of energetic particles from 0.3 keV to 20 keV in 11 bands; the medium energy proton and electron detector (MEPED), that senses protons, electrons, and ions with energies from 30 keV to several tens of MeV; and the high energy proton and alpha detector (HEPAD), that senses protons and alphas from a few hundred MeV up through relativistic particles above 840 MeV. The data from the SEM instruments are included in the HRPT and beacon transmissions.

Data Collection and Location System

The data collection and location system (DCS) is a random-access system that provides a means of obtaining environmental data such as temperature, pressure, altitude, etc., from fixed and/or free-floating terrestrial and atmospheric platforms. The environmental data messages sent by the remote automated platforms vary in length depending on the type of platform and its purpose. The data from each platform contain identification as well as environmental measurements. When necessary, location of the platforms may be computed by differential Doppler techniques using data obtained from the measurement of platform carrier frequency as received on the satellite. When several measurements are received during a given contact with a platform, location can be determined. Accuracy of location depends upon the number of messages received from the platform. Position can be determined to within 3-5 km rms; velocity to within 0.5-1.5 m/s rms. Platform signals are received by the receiver search unit at 401.65 MHz. Since it is possible to acquire more than one simultaneous transmission, four processing channels, called data recovery units (DRU), operate in parallel. After the Doppler frequency is measured, the sensor data are formatted with other internally generated data, and the output is transferred to a buffer interface with the spacecraft data processor (TIP, for TIROS-N information processor).

Data from the DCS are included in the HRPT and beacon transmission. After the stored data is received at the central processing facility, the DCS information is decommutated and sent to the CNES, ARGOS processing center in Toulouse, France. Resulting outputs are sent to system users and are retained on magnetic tape for archival purposes.

Spacecraft Bus

The TIROS-N spacecraft are an adaptation of the defense meteorological satellite program (DMSP) block 5D spacecraft first launched in 1976. Both spacecraft were developed and built by RCA Corporation for NASA and the Department of Defense, respectively. Each TIROS-N satellite is an integrated system designed to provide for the control injection into a nominal 833- or 870-km circular, near-polar, sun-synchronous orbit after separation from the Atlas-E/F launch vehicle. Figure 3 depicts key features of TIROS-N.

Structure

The spacecraft structure consists of four components: 1) the reaction system support structure (RSS); 2) the equipment support module (ESM); 3) the instrument mounting platform (IMP); and 4) the solar array (SA) and drive (SAD). Instruments are located on both the IMP and the ESM. With the exception of the SEM, all instruments face the Earth when the satellite is in mission orientation. The satellite, including the injection motor assembly, is approximately 3.71 m in length in the launch mode and 1.88 m in diameter. Satellite liftoff mass is 1418 kg and the in-orbit mass is 737 kg. Of this mass, approximately 230 kg is used for the payload.

Power System

Spacecraft power is provided by a direct energy transfer system whose primary source is an 11.6-m^2 planar solar array; the secondary source is a pair of nickel-cadmium batteries. The solar array is made up of eight panels of solar cells, each 61.4×237.5 cm. The array, which must be deployed from its launch stowed position, is canted at 36 deg to the orbit normal. A solar array drive system causes the array to rotate once per orbit so that the array continuously faces the sun. Current supplied to the satellite through sliprings during daylight portions of the orbit is used to operate the satellite and to charge the two 26.5 amp-h nickel-cadmium batteries.

These batteries supply spacecraft power during dark portions of the orbit and augment the array during daylight peak load conditions. Total orbit average load capacity for the system is about 420 W at the end of 2 y in orbit at a worst-case sun angle.

Reaction Control Equipment

The TIROS-N satellite includes an integrated system for guidance and control following separation from the Atlas vehicle to orbital injection. The reaction control equipment (RCE) provides ascent phase, attitude control (3-axis), and orbital velocity trim for final injection. The second stage engine, a TE-M-364-15, is integral with the TIROS-N spacecraft. During and after second stage burn, the TIROS-N provides three-axis stabilization utilizing its hydrazine and nitrogen thrusters. The RCE is operational from Atlas separation to the orbital orientation of the satellite after which the system is shutdown.

Attitude Determination and Control

The on-orbit attitude determination and control subsystem (ADACS) provides automatic 3-axis pointing control for the satellite. The ADACS maintains system pointing by controlling torque in three mutually orthogonal reaction wheels (a fourth skewed wheel is available in the event of failure of one of these three). The torque is determined by analysis of spacecraft orientation in space. Inputs to these computations are acquired from the Earth sensor assembly (ESA) for pitch and roll, and an inertial reference with sun sensor updates for yaw. Figure 4 is a simplified block diagram of ADACS. The ADACS controls spacecraft attitude to maintain orientation of the three axes to within ±0.2 deg (3σ) of the local geographic reference. Information is also available to permit the yaw, pitch, and roll that existed at any particular time to be computed to within 0.1 deg by computer processing on the ground. Analysis has shown that except for short duration perturbations of up to 0.2 deg, the attitude is generally maintained to within approximately 0.12 deg. The ADACS is a nominally zero momentum control system which includes: 1) an Earth sensor assembly (ESA); 2) a sun sensor assembly

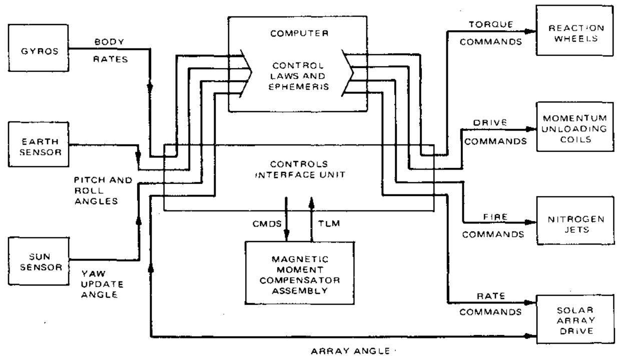

Fig. 4 ADACS block diagram.

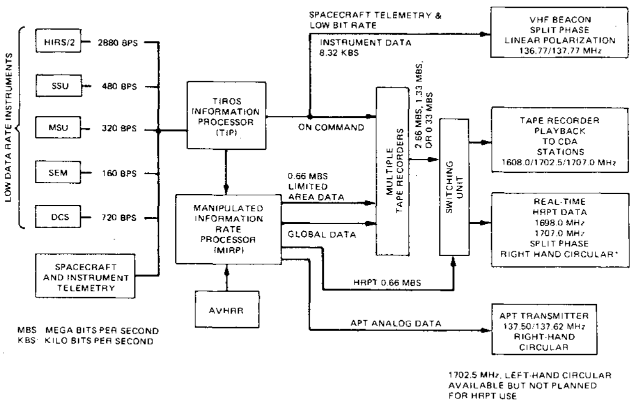

Fig. 5 TIROS-N data flow diagram.

(SSA); 3) four reaction wheel assemblies (RWA's); 4) magnetic control coils; and 5) inertial measurement unit (IMU).

The ESA is a static infrared (15 μm region) sensor designed to operate over the range of 740-926 km. Nominally, the Earth is centered between four independent detectors which view a segment of the horizon in each of four quadrants. If the Earth view were perfectly centered, the spacecraft roll and pitch error would be zero. In practice, pitch and roll are determined from these readings, and the control system tries to keep the error as close to zero as possible.

The SSA is a single-axis digital sun sensor whose output is used to compute the satellite yaw attitude error. The calculated yaw error is used to update the spacecraft yaw attitude once per orbit. Attitude changes between this update and the following update are derived from the combined yaw, roll, and pitch gyro outputs.

The RWA's provide active attitude control by generating reaction torques about the three orthogonal spacecraft axes. Three of the RWA's are mounted orthogonally to produce torques about each of the three primary spacecraft axes; the fourth RWA is canted at an angle of approximately 54.7 deg with respect to each of the three axes, so that a portion of its torque resolves into all three of the axes. This fourth RWA is normally idle unless one of the orthogonal RWA's fails.

Two magnetic torquing coils (a pitch coil and a roll/yaw coil) included in the ADACS provide a capability for unloading accumulated satellite momentum. Current flowing in these coils generates an electric field that interacts with the Earth's magnetic field to remove momentum.

The ADACS also contains four gas-bearing, rate-integrating gyros. Like the RWA's, three gyros are orthogonal, while the fourth is canted to the spacecraft control axes. The gyros measure the attitude rates around each of the three axes for control-loop damping and for deriving yaw attitude between periodic sun-sensor determinations.

Thermal System

The thermal design of the satellite provides accurate temperature control of both the spacecraft structure and the instrument payload. Both active and passive elements are used for this purpose.

Data Handling System

The TIROS-N data handling subsystem, as shown in Fig. 5, consists of the following primary components: 1) the TIROS information processor (TIP); 2) the manipulated information rate processor (MIRP); and 3) five digital tape recorders (DTR's).

The TIP formats all low bit-rate instrument and telemetry data available for transmission from the satellite. It also controls the data outputs from these sources (instruments and satellite systems), and accepts command verification data. The TIP adds synchronization, identification, and time code before simultaneously transferring the data to the beacon transmitter, tape recorder interface (by command), and MIRP. Within the MIRP, the TIP data is combined within three output data formats (HRPT, global stored, and limited area stored).

The MIRP processes data from the AVHRR to provide separate outputs for: 1) HRPT transmission in real time, 2) APT transmission in real time, 3) tape recorded global area coverage (GAC) for central processing of reduced resolution data, and 4) tape recorded local area coverage (LAC) for central processing of selected areas of high-resolution data. The MIRP, in addition to formatting, adds synchronization, identification, telemetry, time code, and (except for APT) the TIP output to the AVHRR. The high resolution AVHRR is reduced in resolution by averaging for both APT and GAC uses.

The five digital tape recorders, each with a single electronic module and dual tape transport, provide recorded data for subsequent transmission through the CDA to the central data processing facility. Each transport has an adequate tape capacity to record approximately 4.5×10^8 bits of data.

Command and Control

The command and control group provides the functions for decoding ground commands, storing commands for later execution, and issuing control signals. Redundant crystal oscillators (RXO) are used to provide a highly stable frequency source for all spacecraft clock-related functions.

The controls interface unit (CIU) obtains data and control signals from the spacecraft computer, buffers them, and transmits them to other spacecraft components for action. It also contains all the circuitry necessary to generate the clocks and timing signals used by the satellite.

Two central processing units (CPU's) regulate the final stages of injection into orbit by computing required thrust levels and issuing control commands to the reaction control equipment. The CPU's also control operation of the satellite in orbit and issue commands to maintain spacecraft attitude within predetermined limits.

Communications System

The primary communications links are shown in Table 1 (extracted from Ref. 2). Each of the three 5.25-W output S-band transmitters is coupled to one of three quadriphase antennas. Normally, one of the transmitters is used continuously for transmission of HRPT data while the other two are used to play back tape recorders to one of the centralized data acquisition stations. All three transmitters may be used in parallel when required to retrieve data from the onboard recorders. Two of the S-band antennas are right-hand circularly polarized (1698 and 1707 MHz), while the third is left-hand circularly polarized (1702.5 MHz). During the ascent phase only, one of the S-band transmitters is connected to an S-band omnidirectional antenna to provide spacecraft telemetry.

Each of the two VHF APT transmitters has a 5-W output and operates at a preselected frequency of either 137.50 or 137.62 MHz. One of the transmitters operates continuously. The transmitting frequency is chosen to preclude interference between signals emanating from two satellites in orbit at the same time. Either transmitter is coupled to the VHF real-time quadrifilar antenna via an rf switch. The signal is an amplitude-modulated 2.4-kHz subcarrier which frequency modulates the carrier. The antenna, a four-element quadrifilar, provides a shaped pattern.

Launch and Orbit Constraints

The TIROS-N satellite series has been designed to operate in a sun-synchronous orbit at 833 + 90 km. The choice between nominal altitudes is made to keep the orbital periods of two operational satellites in similar orbits sufficiently different (1 min) so that they do not both view the same point on the Earth at the same time each day. Nominal orbital parameters are 833 or 870 km altitude, 98.7 or 98.9 deg inclination, 14.1 orbits, per day.

Equator Crossing Time

The TIROS-N satellite series has been designed to operate with a southbound equator crossing between 0600 and 1000

Table 1 Communication link summary

Link	Carrier frequency, MHz	Information signal	Baseband bandwidth	Modulation
Command[a]	148.56	Digital commands	1 kbps	Ternary FSK/a.m.
Beacon	137.77 or 136.77	Low bit rate instrument data and spacecraft telemetry. All from TIP	8320 bps	Split-phase PSK
VHF Real-time: APT	137.50 or 137.62	Medium resolution video	2 kHz	AM/FM
S-Band Real-time: HRPT	1698 or 1707[b]	High resolution video data, and TIP data from MIRP	665.4 kbps	Split-phase PSK
S-Band play-back to CDA's	1698, 1702.5 or 1707	High resolution video data from MIRP, medium resolution video data from MIRP	2.6616 Mbps	Randomized NRZ-PSK
Data collection[a]	401.65	Data from Earth-based platforms and balloons	400 bps	Split-phase PSK
S-Band TIP data playback	1698, 1702.5 or 1707	TIP data recovered from tape recorders	332.7 kbps	Split-phase PSK

[a] Uplink to the satellite. [b] 1702.5 may be used for HRPT in the event of failure of primary transmitters.

local solar time (LST), or a northbound equator crossing between 1400 and 1800 LST. The morning satellite is launched into a 0730 LST descending orbit, while the afternoon satellite is launched into a 1500 LST ascending orbit.

Orbit Injection

Satellites of the TIROS-N series are launched into sun-synchronous orbits. The first-stage booster is an Atlas E/F; second-stage propulsion is provided by a rocket motor integral with the satellite.

The guidance system of the Atlas vehicle controls the first stage of the launcher sequence. The spacecraft system monitors the launch parameters and controls the flight after the spacecraft is separated from the Atlas vehicle. Body rates and accelerations are provided to the CPU by the IMU, which is made up of rate integrating gyros and accelerometers. The CPU uses a stored set of equations to determine the optimum flight profile which, after first stage separation, is maintained by the reaction control system (RCS). Hydrazine and nitrogen thrusters are used to provide spacecraft control during the 364-15 apogee kick motor burn and to trim orbital velocity after spacecraft insertion into orbit. These thrusters are also used during the period when the solar array is deployed. Unused nitrogen gas is retained on the satellite for use in the event of unexpected momentum buildup during the lifetime of the satellite.

TIROS-N/NOAA Operational System Elements

The two primary NOAA command and data acquisition (CDA) stations are located near Gilmore Creek, Alaska, and Wallops Island, Virginia. Programming and commanding of the satellite originates at the NESS satellite operations control center (SOCC) located in Suitland, Maryland. The commands, satellite telemetry and environmental data are relayed between the SOCC and CDA's via a commercial communications satellite, RCA Satcom, in geostationary orbit at 119 deg west longitude. This domestic satellite communications system, which includes the "Earth stations" at Gilmore and Wallops, delivers the data to the SOCC at 1.33 megabits/s. The CDA's communicate with the TIROS-N satellite by means of the S-band links and read out the data stored on the satellite's digital tape recorders in addition to receiving direct data transmission during the satellite contact.

The TIROS-N operational system data flow is illustrated in Fig. 6 (extracted from Ref. 1). The TIROS-N ground system consists of two major subsystems, the data acquisition and control subsystem (DACS), and the data processing and services subsystem (DPSS). The DACS includes components at the two NOAA CDA stations, at the satellite operations control center, at the Western European station in Lannion, France, and at the satellite field services station in San Francisco. All the DPSS components are in the NOAA facility at Suitland, Maryland.

The DACS includes all components necessary to command and control the spacecraft, monitor its "health" via housekeeping telemetry, and to retrieve and transmit the spacecraft environmental data to the DPSS processing and data handling facility. The DPSS subsystem ingests the raw satellite data, preprocesses and stores it along with appended auxiliary information such as Earth location and quality control parameters. This subsystem consists of several unique segments of high speed computers, intermediate disk storage units, and a mass data storage system. The quantitative products are then distributed to various government meteorological forecast centers, both in this country and abroad.

Future of the TIROS-N NOAA Satellite System

The TIROS-N type satellites have been designed with sufficient space, mass, and data-handling capability to allow additional instruments to be installed. New instruments

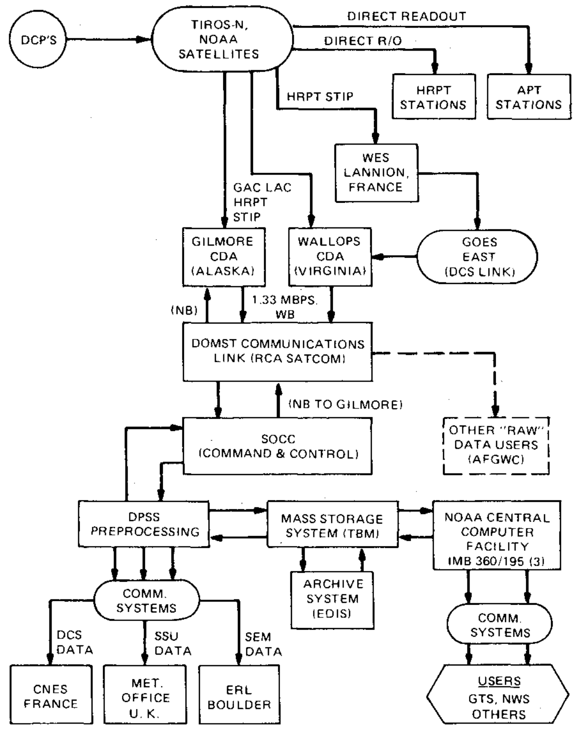

Fig. 6 TIROS-N operational system data flow diagram.

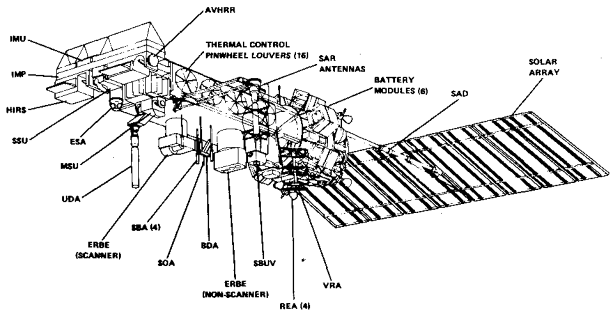

Fig. 7 Advanced TIROS-N spacecraft.

currently planned for inclusion within this growth capability are: 1) a search and rescue (SAR) system comprised of repeater and processor units; 2) a solar backscatter ultraviolet radiometer (SBUV/2); and 3) two Earth radiation budget experiment (ERBE) instruments (a scanner and a nonscanner version).

The spacecraft configured with these instruments will be known as the Advanced TIROS-N (ATN) spacecraft. The ATN design will be incorporated into the last three spacecraft of the TIROS-N series: NOAA-E, -F, and -G. The SAR payload will be included on NOAA-E, -F, and -G, and the ERBE and SBUV/2 will be included on NOAA-F and -G. Figure 7 highlights the ATN configuration.

The ATN spacecraft bus will have a modified, elongated (approximately 50 cm longer than TIROS-N) design, including an additional set of pinwheel thermal control louvers. The planned launch weight of the ATN spacecraft, 1693 kg including the apogee motor, is a 270 kg increase over the TIROS-N spacecraft. The basic instrument payload, with the exception of the new instruments, will remain essentially the same as that flown on TIROS-N.

The search and rescue (SAR) experiment to be installed on ATN will enable detection and location of downed aircraft or marine vessels in distress on a timely basis and dramatically reduce casualty losses by alerting potential rescue teams and guiding them to disaster scenes. The SAR system will detect signals from aircraft emergency locator transmitters (ELT's) and from emergency position identification radio beacons

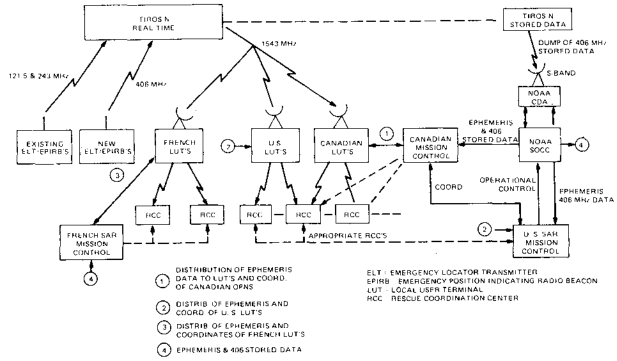

Fig. 8 SAR mission.

(EPIRB's) on ships. ELT's and EPIRB's transmit distress signals on 121.5 or 243 MHz automatically. A new and improved ELT operating on 406 MHz is to be introduced. It will have more power (5 W), more stable crystals, and a user identification code.

The SAR experiment is a joint U.S.-Canadian project. Canada will furnish the communication repeaters for receiving distress signals at 121.5, 243, and 406 MHz and for real-time relay of the search-and-rescue data to the ground sites at 1543 MHz. In addition to the repeater mode of operation, the 406-MHz signal will be processed by the satellite's 406-MHz processor. It will detect the signals, measure the Doppler frequency, and this Doppler data together with the SAR message from the 406-MHz ELT or EPIRB will be transmitted in real time via the 1543-MHz downlink and will also be stored in the spacecraft tape recorders. The 406-MHz processor will be provided by CNES of France.

The 121.5- and 243-MHz signals will be processed by one of the four local user terminals located at Scott Air Force Base, Illinois; San Francisco; Kodiak, Alaska; or at Ottawa, Canada. These stations will use 3-m parabolic antennas, driven automatically by a minicomputer program, to track the ATN satellite. When the satellite is in view of both the distress transmitter and the ground terminal, the ELT or EPIRB signal will be detected and tracked. The Doppler data extracted will then be used to calculate the position of the distress signal. A minimum of 4 min of contact time is needed to determine location by Doppler. The relayed distress signals (121.5 or 243 MHz) will be processed to determine positive location of the distressed vehicle; the 406-MHz signal will be transmitted in real time or stored. When processed, the 406-MHz will provide the location of the distress, identify the vehicle in distress, and display a message concerning the nature and time of the distress. Location accuracy of the 121.5- and 243-MHz signals will be 10-20 km; that of the 406-MHz signal will be between 2-5 km. Figure 8 diagrams the SAR mission data flow.

The USSR, as well as other countries, has expressed interest in participating in the SAR experiment.

Use of TIROS-N Data

Over the past 20 years the quantity, quality, and reliability of satellite coverage have improved greatly. Since 1966 the entire Earth has been photographed at least once daily on a continuous basis. The photographs are not only used in real-time operations, but are also placed in archives from which they can be retrieved for use in research case studies. Satellite data are now being used by meteorologists and environmental scientists on a widespread basis in routine operations throughout the world, and is considered almost indispensable for analyses and short-range forecasts.

The satellite data has proved extremely useful in two broad types of situations. First, there are extensive areas of the Earth from which conventional reports are sparse, namely: the oceanic regions of the northern and southern hemispheres, the deserts, and the polar regions. Satellite data fills these voids by locating the large-scale features depicted by the cloud formations. These features include storm systems, fronts, upper level troughs and ridges, jet streams, fog, stratus, sea ice conditions, area of snow cover, and to some extent upper level wind directions and speeds. The satellite data are also used in conjunction with other data to provide quantitative heights of constant pressure surface as inputs to conventional analyses.

The second type of situation to which satellite data is usefully applied is the location and tracking of hurricanes, typhoons, and tropical storms. Coastal and island stations with little or no adjacent conventional weather information can make maximum use of APT data and the processed stored data from facsimile circuits. The satellite data provides information on the presence and position of frontal patterns, storms, and general cloud cover.

The infrared data from the TIROS/NOAA satellites can be used to produce charts showing the sea-surface temperature over a larger area and with more frequency than is possible from any other source. This data is useful to shipping interests and the fishing industry, and is a vital input to meteorological forecasts. Satellite pictures display the extent and character of ice fields in the Arctic and Antarctic Seas, and on the Great Lakes, with a frequency and geographic coverage never before approached.

Worldwide atmospheric temperature soundings provided by the satellite result in more complete and accurate analyses for use in weather forecasts. Soundings by satellite provide coverage over oceans and remote areas not covered by conventional sounding instruments. Individual soundings from satellites aid in the interpretation of satellite picture data by providing correlation at specific geographical locations. The continual soundings enable the location of atmospheric temperature gradients for use in studying atmospheric phenomena.

Conclusions

The TIROS-ESSA-ITOS-NOAA family of satellites has fulfilled U.S. operational requirements by providing a reliable in-orbit system that transmits routine observations on a timely basis without interruption in service. Its evolutionary design has permitted a cost-effective approach in achieving program objectives and provided a gradual and effective improvement in service with existing worldwide receiving stations. With the advent of the Advanced TIROS-N, further improvements in observation and in the processing and dissemination of data will be provided.

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