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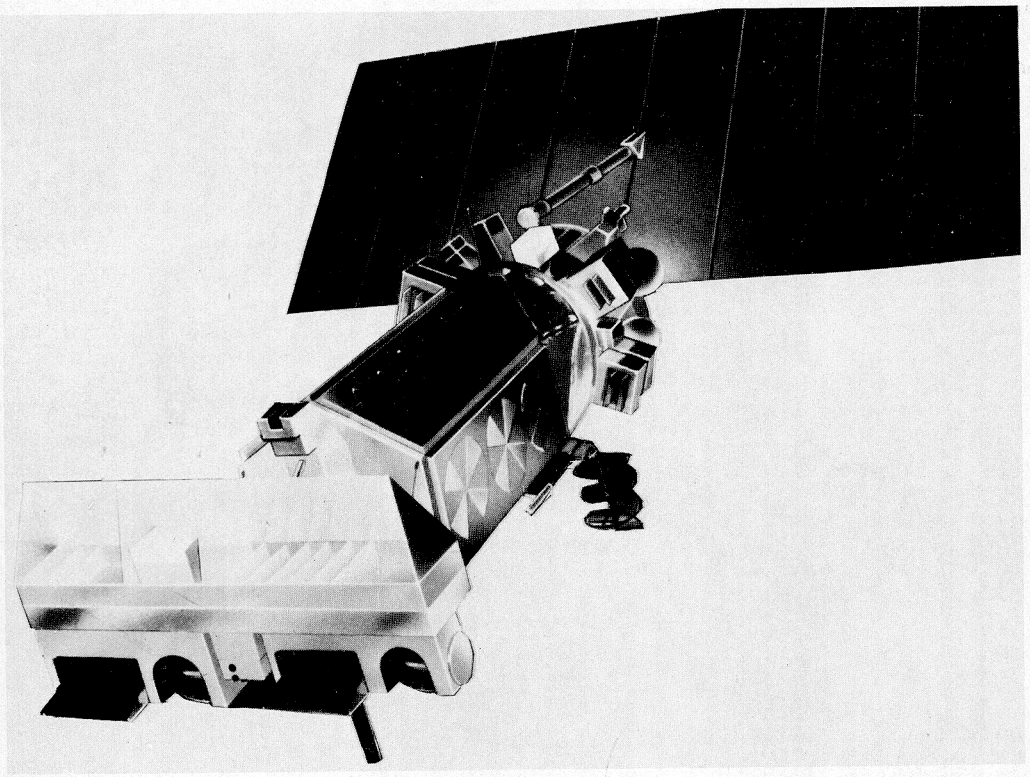
THE TIROS-N/NOAA OPERATIONAL SATELLITE SYSTEM



by

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U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

National Environmental Satellite Service

Washington, D.C.

National Oceanic and Atmospheric Administration
TIROS Satellites and Satellite Meteorology

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ABSTRACT

The Improved TIROS Operational Satellite (ITOS) was the second generation of NOAA operational polar orbiting spacecraft. This series served the nation's environmental needs from October 1972, until March 1979 when the last ITOS spacecraft, NOAA-5, was put on "standby duty".

The third generation polar system, TIROS-N, carried into space new environmental instruments which are major technological advances over ITOS. Specifically these new capabilities include:

(1) Higher resolution, day and night cloud cover observations on a local and global scale.

(2) Improved observations of vertical temperature and water vapor profiles on a global scale.

(3) First operational flight of a high capacity data collection and platform location system.

TIROS-N was launched on October 13, 1978, and is the current NOAA operational polar orbiting satellite. The second of this dual satellite system, NOAA-A, is scheduled for launch in May 1979. It will be designated NOAA-6 once in orbit.

This paper discusses the TIROS-N/NOAA-A spacecraft, instrument payload and the ground data processing and handling system operated by NOAA.

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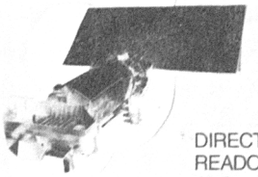
NATIONAL ENVIRONMENTAL SATELLITE SERVICE



DIRECT
READOUT TO
GLOBAL
USERS

TIROS·N
POLAR
ORBITING
SATELLITE

SMS/GOES
GEOSTATIONARY
SATELLITE

RELAYED
AND DIRECT
BROADCASTS
TO WESTERN
HEMISPHERE
USERS

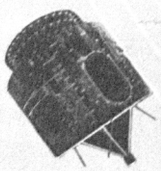


TABLE OF CONTENTS

I. Introduction

II. Orbit Description

III. Spacecraft Overview

A. General Spacecraft Description

B. Telecommunications System

C. Primary Instrument Systems

D. Direct Readout Imaging Systems

IV. TIROS-N/NOAA Operational System Elements

V. Future of the TIROS-N/NOAA Satellite System

1. INTRODUCTION

The United States' civilian operational environmental satellite systems are operated by the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite Service (NESS). The basic mission objectives of this operational satellite program include:

A. Monitoring the atmosphere regularly and reliably on a global basis, day and night, with direct readout to local ground stations around the globe within radio range of the satellites.

B. Sounding the atmosphere regularly on a global basis and providing quantitative data for numerical weather prediction services.

C. Continuous monitoring of environmental features in the western hemisphere, and the collection and relay of environmental data from remote platforms such as buoys, ships, automatic stations, aircraft, and balloons.

D. Applying environmental satellite data for the purpose of improving environmental services.

This program includes two different types of environmental observation satellites. They are the Geostationary Operational Environmental Satellites (GOES) and the new third generation operational polar orbiting system called TIROS-N.

The TIROS-N series of satellites carries a TIROS Operational Vertical Sounder (TOVS), an Advanced Very High Resolution Radiometer (AVHRR), a Space Environment Monitor (SEM), and a Data Collection and Platform Location System called ARGOS. The major improvements over the previous ITOS system provide higher accuracy and increased yield of atmospheric temperature and water vapor sounding, increased spectral radiometric information for more accurate sea-surface temperature mapping and delineation of melting snow and ice fields, a remote platform location and data collection capability, and increased proton, electron, and alpha particle spectral information for improved solar disturbance prediction. The previously established direct broadcast services, including night and day cloud cover

and sounder data transmission, are continued in this new system.

The TIROS-N series of satellites is a unique cooperative effort of the United States, the United Kingdom, and France. NASA funded the development and launch of the first flight satellite (TIROS-N); subsequent satellites will be procured and launched by NASA using NOAA funds. The operational ground facilities including the Command and Data Acquisition (CDA) stations, the Satellite Operations Control Center, and the data processing facilities (with the exception of the ARGOS Data Collection System (DCS) processing facility) are provided and operated by NOAA. The United Kingdom, through its Meteorological Office provides a Stratospheric Sounding Unit (SSU), one of the three sounding instruments for each satellite. The Centre National d'Etudes Spatiales (CNES) of France provides the DCS instrument for each satellite and the processing facilities for the data obtained from this system. The Centre d'Etudes de la Meteorologie Spatiale (CEMES) of France provides ground facilities for receipt of sounder data during the orbit periods which cannot be tracked by NOAA's ground stations.

II. ORBIT DESCRIPTION

Atlas-E/F Launch Vehicle

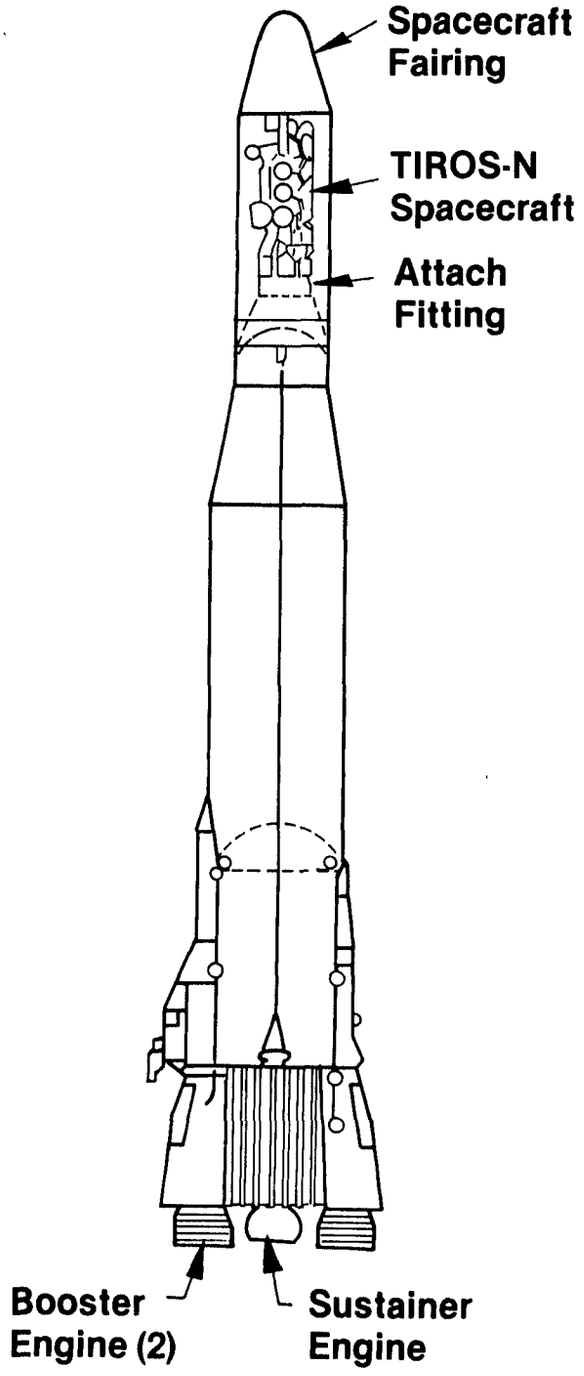


Figure 1.

The TIROS-N spacecraft and launch vehicle configuration are shown in Figure 1. The TIROS-N spacecraft was launched from the Air Force Western Test Range (AFWTR) at Vandenberg Air Force Base, California, on October 13, 1978, at 11:23:00:18 GMT by an Atlas-F launch vehicle. This vehicle has an overall height of 28.2 meters and a maximum body diameter of 3 meters. The approximate total launch weight is 580,356 kg.

The vehicle is powered by a sustainer and two booster engines using liquid oxygen and liquid hydrocarbon propellants. A 0.97 m diameter attach fitting fastens the TIROS-N spacecraft to the launch vehicle. The fairing attached to the forward face of the launch vehicle protects the spacecraft from aerodynamic heating during the boost phase of launch.

The second stage is a solid rocket motor containing about 658 kg. of propellant and is an integral part of the spacecraft. Its propellant burns to depletion and the motor assembly case, weighing 48 kg., is left in orbit with the spacecraft. Three-axis stabilization of the spacecraft during the second stage burn is provided by nitrogen and hydrazine thrusters.

The initial TIROS-N spacecraft was launched into an afternoon orbit with local equator crossing at 1500L. As shown in Table 1, it is in a near polar, sun synchronous orbit at an average altitude of 854km as compared with the average 1475km altitude of the previous ITOS satellites. The second satellite, NOAA-A, will be flown at a somewhat lower altitude of 833km in order to avoid extended periods of readout conflict.

Table 1.

TIROS-N/NOAA Orbit Parameters

• Orbit Type:	Near Polar, Sun Synchronous
• Semi-Major Axis:	7231.8km
• Eccentricity:	0.00118
• Inclination:	98.91 Degrees
• Nodal Period:	102 Minutes (14.2 Orbits Per Day)
• Average Altitude:	854km (TIROS-N) 833km (NOAA-A)
• Equator Crossing Times:	
Morning Orbit:	0730 Local Descending (NOAA-A)
Afternoon Orbit:	1500 Local Ascending (TIROS-N) With Drift Rate of 10 Minutes Later Per Year.

The orbital period is 102 minutes for TIROS-N as compared with 115 minutes for the ITOS satellites. This produces 14.2 orbits per day. Because the number of orbits per day is not an integer number, the suborbital tracks do not repeat on a daily basis, although the local solar time is essentially unchanged for any latitude. For this reason, the orbital equator crossings occur at varying longitudes. Acquisition time for overhead passes is reduced approximately 35 percent from the ITOS time and fewer passes of a single satellite are within acquisition range. However, the operational system consists of a morning orbit (0730L descending) and an afternoon orbit (1500L ascending).

The afternoon satellite (1500L) fulfills the majority of user needs for visible data. The morning satellite (0730L) will contain the earth's shadow in a large part of the visible imagery in the winter hemisphere. The quantitative requirements such as sea surface temperature observations are obtained from the thermal infrared data and are not affected by orbit times. Considerable analyses were performed

to select the equator crossing times to provide the best geographic coverage per synoptic data window and timely data retrieval and processing to meet the National Meteorological Center (NMC) analysis cycles.

Orbit prediction for TIROS-N requires more sophisticated prediction techniques than those used to predict the ITOS orbits. In particular, gravitational forces which are relatively insignificant for a 1475km ITOS-type orbit become much more significant for a spacecraft operating at an altitude of 854km. Additionally, solar effects during the period of maximum solar activity in 1980 will introduce significant perturbations to the orbit.

Figure 2 depicts the TIROS-N orbit and its relationship to the earth's terminator.

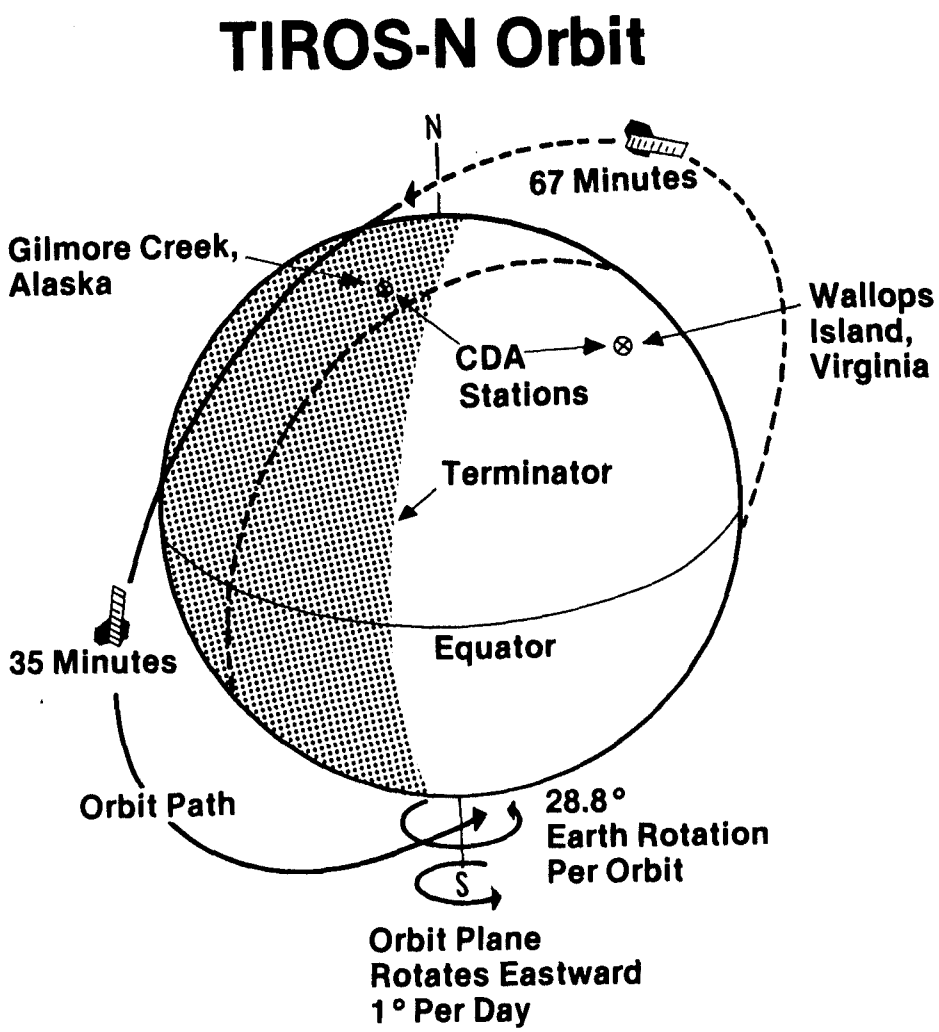


Figure 2. TIROS-N Orbit

III. SPACECRAFT OVERVIEW

A. GENERAL SPACECRAFT DESCRIPTION

The TIROS-N/NOAA-A spacecraft as shown in Figures 3 and 4 is a five-sided box-like structure which is 3.71 meters long and 1.88 meters in diameter. Four of the side faces are equal in size and accommodate a total of twelve thermal control louvers. The fifth side is wider than the other four and accommodates the earth-facing communications antennae and some of the earth viewing sensors. The spacecraft weighed a total of 1421kg at launch including expendables.

At one end of the central body known as the Equipment Support Module (ESM) is the Reaction Support Structure (RSS) which includes the last stage launch injection motor, an attitude control propulsion system and a boom-mounted solar cell array. The solar array is 11.6 sq. meters in size and is motor driven to rotate once per orbit so that it will continuously face the sun during the daylight portions of the orbit.

At the other end of the ESM is the highly stable Instrument Mounting Platform (IMP) on which are mounted the attitude control sensors and the instruments whose scan directions must be very accurately controlled. With the exception of the Space Environment Monitor (SEM), all instruments face the earth when the satellite is in its mission mode. The earth oriented platform will be controlled to within $\pm 0.2^{\circ}$ of the local geographic reference for all axes.

A most important spacecraft subsystem is the data handling subsystem which consists of four primary components:

1. TIROS Information Processor (TIP)

2. Manipulated Information Rate Processor (MIRP)

3. Digital Tape Recorders

4. Cross Strap Unit

All data available for transmission to the ground are processed by some or all of these components. The TIP formats all low bit rate instrument and housekeeping telemetry data and controls the data outputs. The instrument data which are processed by the TIP include the TIROS Operational Vertical Sounder (TOVS), the Space Environment Monitor (SEM), and the Data Collection System (DCS). The individual instrument data rates going into the TIP are listed below:

HIRS/2	2880 bits per second
SSU	480 " " "
MSU	320 " " "
SEM	160 " " "
DCS	720 " " "

The TIP data are output as serial digital words at 8320 bits per second and are included in the real time beacon transmission and recorded data.

The MIRP processes the high rate data from the Advanced Very High Resolution Radiometer (AVHRR) in order to provide separate outputs for Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) in real time, recorded Global Area Coverage (GAC) of reduced resolution data and recorded Local Area Coverage (LAC) of high resolution data for commanded readout at the CDA's and processing in the NOAA central computer facility at Suitland, Maryland. The four data formats are output simultaneously. LAC is similar to the recorded HRPT data of the ITOS system known as VREC.

In addition to formatting, the MIRP adds synchronization, identification, time code, telemetry and the TIP output to the AVHRR data. The high resolution AVHRR is reduced in resolution by averaging techniques for use in the APT and GAC formats. The HRPT and LAC are output from the MIRP at 0.66 mega bits per second while the APT is in analog form.

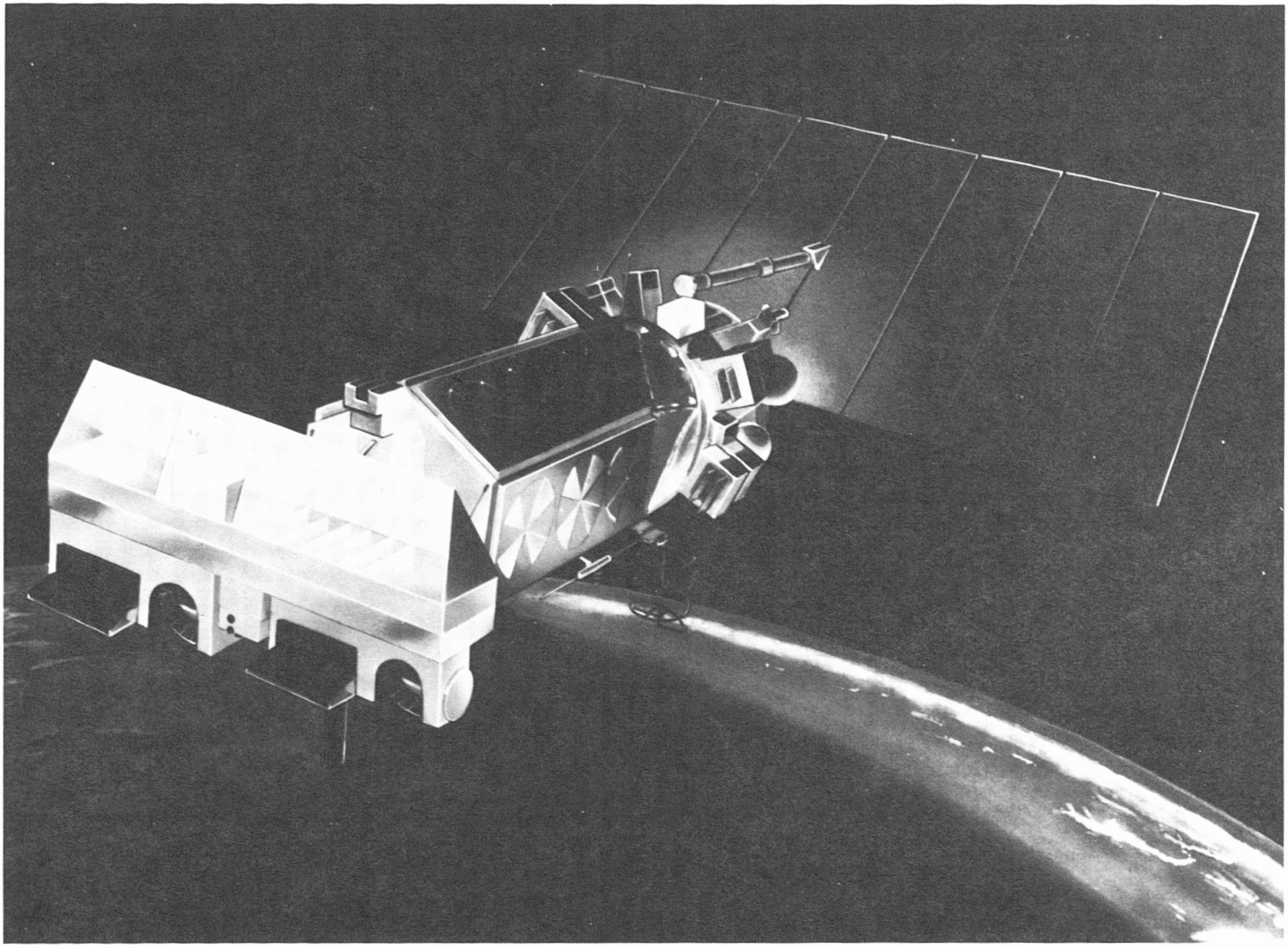


Figure 3. TIROS-N/NOAA Spacecraft

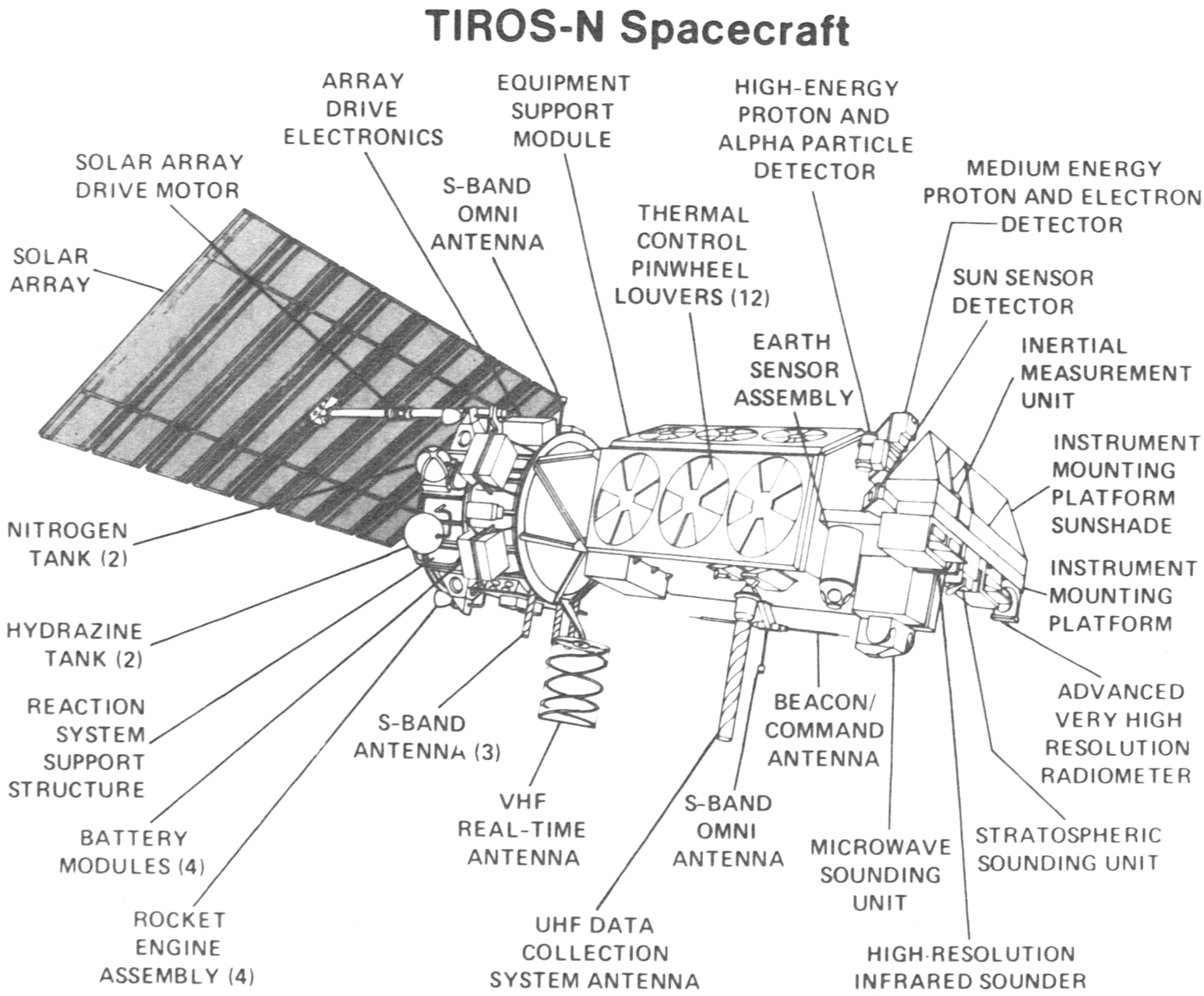


Figure 4. TIROS-N Spacecraft Diagram

B. TELECOMMUNICATIONS SYSTEM

The TIROS-N telecommunications system consists of S-band, UHF and VHF data links. Table 2 below summarizes the characteristics of the TIROS-N communication links.

Table 2.

Communications Link Summary

Link	Carrier Frequency	Information Signal	Baseline Bandwidth	Modulation
1. Beacon	137.77 MHz or 136.77 MHz	Low Bit Rate Instrument Data and Spacecraft Telemetry, All From TIP	8320 bps	Split-Phase PSK
2. VHF Real-Time —APT	137.50 MHz or 137.62 MHz	Medium Resolution Video Data From MIRP	2 KHz	AM/FM
3. S-Band Real-Time —HRPT	1698 or 1707* MHz	High Resolution Video Data and TIP Data From MIRP	665.4 kbps	Split-phase PSK
4. S-Band Playback to CDA's	1698, 1702.5 or 1707 MHz	High Resolution and Medium Resolution Video Data From MIRP	2.6616 Mbps	Randomized NRZ-PSK
5. Data Collection (Uplink Only)	401.65 MHz	Data From Earth Based Platforms and Balloons	400 bps	Split-Phase PSK
6. S-Band TIP Data Playback	1698, 1702.5 or 1707 MHz	TIP Data Recovered From On-Board Recorders	332.7 kbps	Split-Phase PSK
7. Command Uplink	148.56 MHz	Digital Commands	1 kbps	Ternary FSK/AM

*1702.5 MHz may be used for HRPT in the event of failure of primary S-band Transmitters.

There are three S-band transmitters which can be used to transmit any of the high resolution video and stored sounding data. Normally, one of the transmitters will be used

continuously for transmission of HRPT data while the other two are used to playback tape recorders to the CDA's. The VHF APT transmitter operates at either 137.50 or 137.62 MHz as did the ITOS/NOAA satellites. Choice of transmitting frequency will be made to preclude interference between signals emanating from two satellites close in orbit at the same time. The UHF data collection communications frequency (401.65 MHz) is for uplink only from earth-based platforms and balloons.

C. PRIMARY INSTRUMENT SYSTEMS

The four primary spacecraft instrument systems are listed below:

1. Advanced Very High Resolution Radiometer (AVHRR)
2. TIROS Operational Vertical Sounder (TOVS)
3. Data Collection System (DCS)
4. Space Environment Monitor (SEM)

1. Advanced Very High Resolution Radiometer (AVHRR)

The Advanced Very High Resolution Radiometer (AVHRR) provides data for real-time transmission to both APT and HRPT users and for storage on the spacecraft digital tape recorders for later playback. Thus, the AVHRR instrument continues and improves upon the ITOS/NOAA satellite services related to stored and direct readout of radiometric data for day and night cloud mapping, sea surface temperature mapping and other oceanographic and hydrologic applications. The data from the AVHRR instrument is available from the satellite in four operational modes:

A. Direct readout to ground stations of the Automatic Picture Transmission (APT) class, worldwide, at 4km resolution, of the visible and infrared data. Panoramic distortion is removed.

B. Direct readout to ground stations of the High Resolution Picture Transmission (HRPT) class, worldwide, at 1.1km resolution in all spectral channels.

C. Global on-board recording of 4km resolution data from all spectral channels; Global Area Coverage (GAC), for commanded readout for processing in the NOAA central computer facility at Suitland, Maryland.

D. On-board recording of data from selected portions of each orbit at 1.1km resolution in all spectral channels; Local Area Coverage (LAC), also for central processing.

The AVHRR for TIROS-N and four of the follow-on spacecraft is sensitive in four general regions (see Table 3 following). A future change in the instrument design will add a fifth channel in the 12 micrometer region. The resulting five channel instruments called AVHRR/2, are planned for flight on NOAA-C or -D and also on NOAA-F and -G.

Table 3.

TIROS-N AVHRR Channel Characteristics

Channel*	Resolution at Subpoint	Wavelength (μm)	Primary Use
1	1 km	0.55 — 0.90	Daytime Cloud and Surface Mapping
2	1 km	0.725 — 1.10	Surface Water Delineation
3	1 km	3.55 — 3.93	SST, Nighttime Cloud Mapping
4	1 km	10.5 — 11.5	SST, Day/Night Cloud Mapping
5	1 km	11.5 — 12.5	SST

***Channel 1 wavelength will be 0.58-0.68μm for *all* instruments after the TIROS-N flight model. Channel 4 wavelength will be 10.3-11.3μm for all AVHRR/2 instruments. Channel 5 has been added to the AVHRR/2 instrument to further enhance Sea Surface Temperature (SST) measurements in the tropics.**

AVHRR Channels 1 and 2 are used to discern clouds, land-water boundaries, snow and ice extent; when data from the two channels are compared, they provide an indication of ice/snow melt inception. The data from Channel 4 (IR window) is used to measure cloud distribution day and night and to determine the temperature of the radiating surface. Channels 3 and 4 are used to determine the Sea Surface Temperature (SST). By using these two data sets, it is possible to remove an ambiguity introduced by clouds filling a portion of the field-of-view.

2. TIROS Operational Vertical Sounder (TOVS)

The TIROS Operational Vertical Sounder (TOVS) system combines data from three complementary sounding instruments aboard the spacecraft. These instruments are as follows:

A. High Resolution Infrared Radiation Sounder (HIRS/2)
B. Stratospheric Sounding Unit (SSU)
C. Microwave Sounding Unit (MSU)

The primary instrument providing tropospheric data, HIRS/2 is sensitive to energy from the visible to the CO_2 region of the infrared spectrum. This instrument provides data that will permit calculation of temperature profiles from the surface to 10 mb, water vapor content at three levels of the atmosphere, and total ozone content. The HIRS/2 resolution of 17km at the subpoint is much better than the ITOS Vertical Temperature Profile Radiometer (VTPR) which was 55km at the subpoint. The SSU instrument, provided by the Meteorological Office of the United Kingdom, is sensitive to energy in the CO_2 portion of the infrared spectrum and provides temperature information from the stratosphere. The third instrument, the MSU, is sensitive to energy in the oxygen region of the microwave spectrum and is used in conjunction with the two IR instruments. The microwave data permits temperature computation to be made in the presence of clouds since measurements in this region are generally unaffected by non-precipitating water droplets.

Table 4 lists some characteristics of the three TOVS instruments discussed above.

Table 4.

TIROS-N Operational Vertical Sounder (TOVS) Characteristics

Characteristic	Stratospheric Subsystem (SSU)	Tropospheric Subsystem (HIRS/2)	Microwave Subsystem (MSU)
Resolution at Subpoint	147 km	17 km	109 km
Field of View	10°	1.4°	7.5°
General Spectral Regions Used	15 μm CO_2	15 μm CO_2 11 μm Window 9.7 μm 0_3 6.7 μm H_20 4.3 μm CO_2 3.7 μm Window 0.7 μm Visible	50-57 GHz 0_2
Number of Spectral Channels	3	20	4

Data from the TOVS instruments are available on two separate real-time data transmission links. On-board the satellite, the TOVS data are collected and formatted by the TIROS Information Processor (TIP). Parallel outputs are provided for:

1. The real-time VHF beacon transmission link.

2. The Manipulated Information Rate Processor (MIRP) which combines the TIP data with output from the AVHRR. This combined data stream is:

   a. Broadcast in real-time as the High Resolution Picture Transmission (HRPT) service.

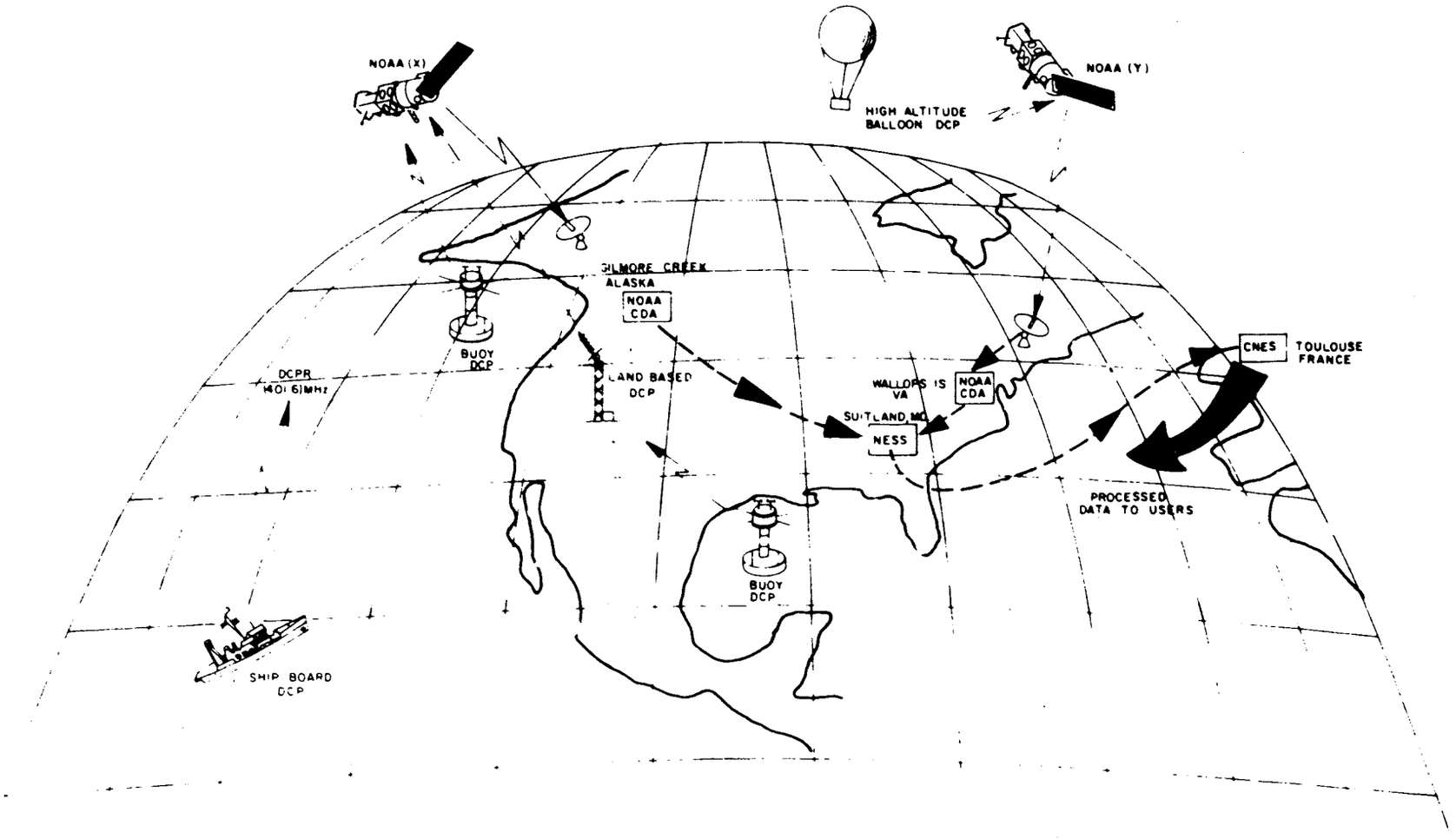
   b. Stored on-board the satellite for later transmission to the ground with the Stored TIP (STIP) data.

It should be noted that all data from the TOVS are digital and that the data included within the HRPT format are identical to that broadcast on the beacon. Data from the TOVS are available on both VHF and S-band data links. Those users receiving the high resolution transmission from the AVHRR (HRPT system) will probably find it most desirable to extract the TOVS data from this data stream. Use of two frequencies for this data is planned so that interference between transmissions from two satellites within view of a station will be eliminated. This problem is particularly severe in high latitudes where overlapping coverage is routine.

The VHF beacon data stream, also with two possible frequencies, is available for users who do not desire to install the more complex equipment necessary to receive data on the S-band frequencies. The lower data rates (8 kilobits/second versus 665.4 kilobits/second for HRPT) permit the user to install less complex and costly equipment to receive the data without degrading its quality.

3. Data Collection System (DCS)

The Data Collection System on-board TIROS-N is provided by the Centre National d'Etudes Spatiales (CNES) of France. The French call this the ARGOS Data Collection and Platform Location System and it is illustrated in Figure 5. The ARGOS DCS provides a means to locate and/or collect data from fixed platforms and moving buoy and balloon platforms. It includes two new services not currently available in the geostationary satellite (GOES) data collection systems. First, it has the capability to determine platform location, using an inverse doppler technique. Second, it is able to acquire data from any place in the world, but most particularly in the polar



ARGOS DATA COLLECTION
SYSTEM

Figure 5.

regions, beyond transmission range of the geostationary satellites.

The ARGOS DCS system receives data from the platforms at the UHF frequency (401.65 MHz). The platforms transmit independently of any interrogation from the spacecraft which uses a random access receiving system. Each platform will make continual transmissions, varying in length from 360 to 920 ms at a repetition interval from 40 to 200 seconds. As the spacecraft passes within range of a platform during its orbit, it receives and records the successive transmissions. Once the spacecraft comes within the range of a CDA, it plays back the recorded data to the ground facility. On the ground the data is forwarded to Suitland, where the ARGOS data is separated from the other spacecraft telemetry data and relayed to the CNES Toulouse Space Center in France. There, the platform locations are computed and the data is prepared for relay to the user. The location information is determined by measuring the platform carrier frequency received by the DCS instrument in the spacecraft at each transmission on two successive passes of the satellite. When several transmissions are obtained from a particular platform, differential doppler techniques are used to determine the platform location to an accuracy of 3-5 km rms.

There is a charge of $20 per platform per day by CNES for the position location computations for moving platforms. There is a charge of $1 per platform per day for data collection services. The aforementioned costs of these services are fixed until January 1, 1980. Data are collected between 7 and 28 times per day according to the latitude on the Earth of the measurement point with the results provided in the form of physical parameters.

With two spacecraft operating in the TIROS-N operational system, a given platform will be in contact with the spacecraft during at least four intervals each day. The intervals will be about six hours apart. During any interval the platform will be "acquired" by the spacecraft on at least two successive orbits, which would provide a minimum of eight reports a day. In the polar areas, where the orbital paths converge, many more contacts are made. Up to twenty or more reports may be acquired, approximating the frequency of coverage available through the geostationary satellites. The minimum interval between data collection and the availability of processed data at Service ARGOS in Toulouse is 1 hour and 45 minutes. The maximum interval would be 3 hours and 25 minutes.

The ARGOS system capacity for data collection without location and a 99 percent probability of collection within 12 hours is 16,000 platforms. For platform location and data collection with a 99 percent probability of location over 24 hours, the system capacity is 4000 platforms. These figures

correspond to 920 and 230 platforms respectively that would be simultaneously "acquired" by the satellite, if the platforms were evenly distributed over the earth's surface.

The ARGOS system will also provide for the immediate rebroadcast of data received from platforms. Only data from platforms so located that both the platforms and the receive site are simultaneously in view of the satellite will be available from this direct broadcast. These data transmissions will be included in the same data stream which contains the direct broadcast of sounder data. The spacecraft VHF beacon transmits the DCS data at the low rate. The data in the direct broadcast will not permit platform location computations. However, for fixed platforms this may provide a simpler method of obtaining data regionally than going through the geostationary systems. In polar regions it will be the only method available. If there is a need to obtain data from platforms more expeditiously than can be provided through the GTS or more economically than by providing separate communications, the direct readout method offers another alternative. Further information regarding the ARGOS system may be obtained by writing to:

Service ARGOS
Centre Spatial de Toulouse
18, Avenue Edouard-Belin
31055 Toulouse Cedex
France

4. Space Environment Monitor (SEM)

The Space Environment Monitor (SEM) measures solar proton flux, alpha particle and electron flux density, energy spectrum and total particulate energy distribution at spacecraft altitude.

The three detectors included within this instrument are: (1) Total Energy Detector, (2) Medium Energy Proton and Electron Detector, and (3) High Energy Proton and Alpha Detector. The Total Energy Detector measures the intensity of particles in the energy bands from 0.3 Kev to 20 Kev. The Medium Energy Proton and Electron Detector senses protons, electrons and ions in the range of 30 Kev to around 60 Kev. The third component, the High Energy Proton and Alpha Detector, senses protons and alpha particles from 370 Kev to around 850 Mev. This instrument augments the measurements currently being made by NOAA's geostationary GOES satellites.

The data from the SEM is stripped out of the TIP data stream and combined with location parameters at the NESS Suitland data processing center and transmitted over a

dedicated data link to NOAA's Space Environment Laboratory (SEL) at Boulder, Colorado. These data are transmitted within one hour of the spacecraft readout. At the SEL in Boulder, the TIROS-N data along with the GOES data are used to monitor the state of solar activity which has a significant effect on terrestrial communications, electrical power distribution and high altitude flight in aircraft such as the Concorde SST.

D. DIRECT READOUT IMAGING SYSTEMS

Local users in line-of-sight of the TIROS-N satellite can receive real-time data directly from the spacecraft. Direct readout stations nominally acquire at least two daytime and two nighttime passes from each spacecraft. TIROS-N broadcasts visible (VIS) and infrared (IR) data from the Advanced Very High Resolution Radiometer (AVHRR) as well as other data from the TIROS Operational Vertical Sounder (TOVS), the Data Collection System (DCS), the Space Environment Monitor (SEM), and the spacecraft housekeeping telemetry. This section describes the direct readout imaging systems of TIROS-N/NOAA-A.

The AVHRR provides the data for transmission to both the Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users. The HRPT data is transmitted at full resolution (1.1km) while the APT output has reduced resolution (4km) to maintain bandwidth constraints. The visible channel is used to provide visible APT imagery during daylight and one IR channel is used constantly (both day and night). A second IR channel replaces the visible channel observations during the nighttime portions of the orbit.

The HRPT system transmits all of the channels. In order to avoid future changes on the spacecraft and ground receiving equipment, the TIROS-N HRPT data format was designed as though the AVHRR were already a five channel instrument. When operating with the initial four channel instrument, the data from Channel 4 (11 μm) is inserted in the data stream twice so that the basic data format is the same for both the four and five channel versions of the AVHRR. Output from the low data rate system on-board the spacecraft is multiplexed with the AVHRR data to become a part of the HRPT output available to direct readout users. The low data rate system includes the three instruments of the TOVS, the SEM, the DCS, and the spacecraft housekeeping telemetry. A comparison of the ITOS HRPT system to the TIROS-N HRPT system is shown in Table 5. The digital data format of the TIROS-N AVHRR transmission is one of the key differences which distinguishes TIROS-N HRPT data transmissions from those of the ITOS satellites.

Table 5.

Comparison of ITOS and TIROS-N HRPT Systems

Parameter	ITOS/HRPT	TIROS-N/HRPT
• Line Rate	400 Lines/Minute	360 Lines/Minute
• Data Channels (Spectral Intervals)	2	4 (Later Flights Will Have Five)
• Data Resolution	1.0km	1.1km
• Carrier Modulation	FM: Analog	Digital Split Phase, PSK
• Transmit Frequency	1697.5MHz	1698.0MHz 1707.0MHz
• Transmit Power	5 Watts	5 Watts
• EIRP (Approximate)	37.0dBm	39.0dBm
• Polarization	Right Hand Circular	Right Hand Circular
• Spectrum Bandwidth	1MHz	Less Than 3MHz

Figures 6 and 7 are examples of products from the TIROS-N HRPT system. The digital blow-up shown in Figure 7 was generated by repeating each spot twice over the area of interest. Figure 8 illustrates the high resolution, recorded Local Area Coverage (LAC) capability of TIROS-N. This image was acquired by NESS soon after the AVHRR instrument was turned on.

Figure 6. TIROS-N AVHRR HRPT visible image taken on February 17, 1979 showing the ice covered Great Lakes and a clear view of the snowcovered northeastern U.S. from the Chesapeake Bay to Maine.

Figure 7. A computer generated digital blow-up of the Figure 6 TIROS-N AVHRR HRPT visible image showing the area from the Chesapeake Bay to Long Island, New York on February 17, 1979.

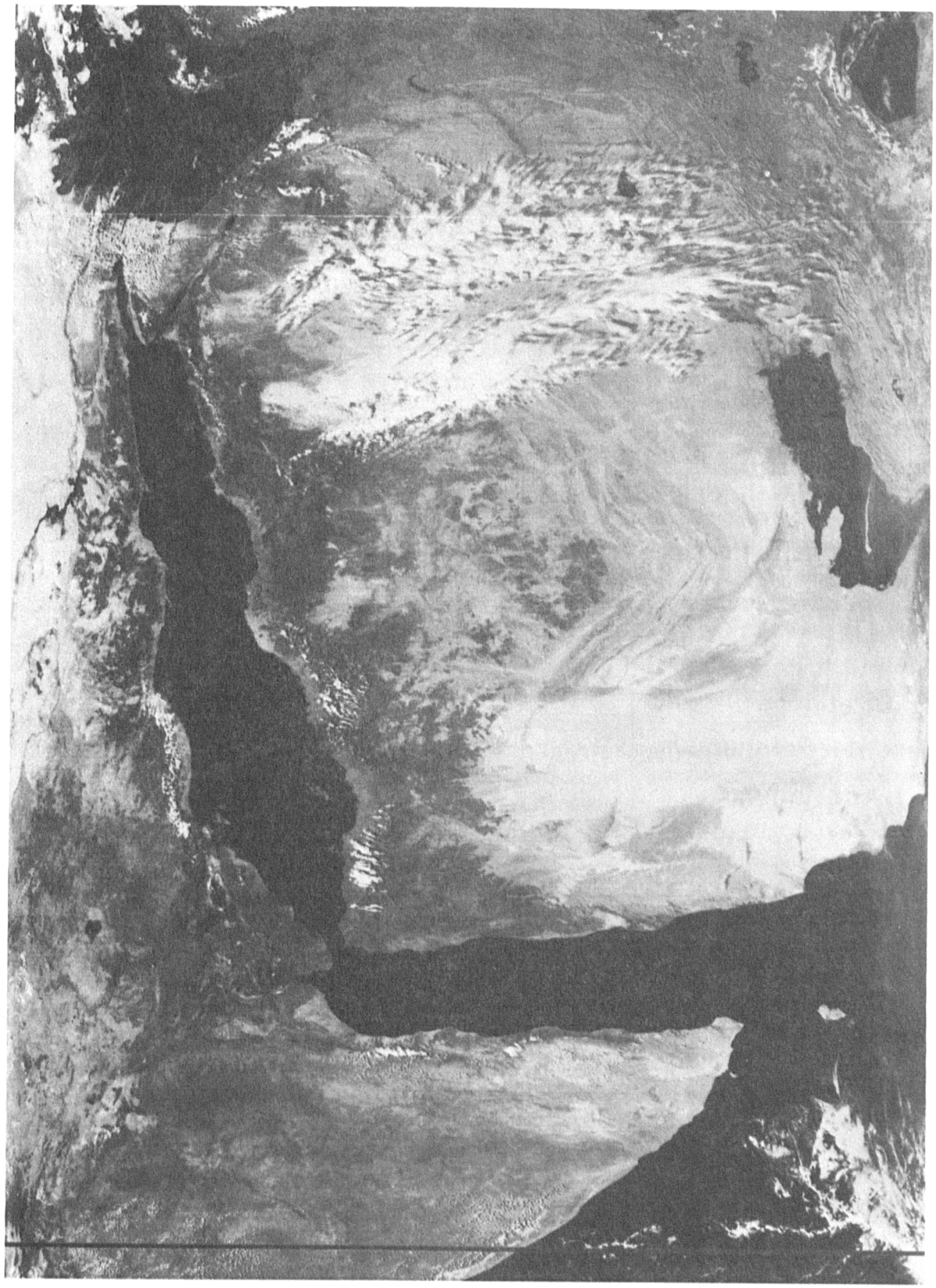


Figure 8. TIROS-N AVHRR recorded onboard Limited Area Coverage (LAC) visible image taken on November 6, 1978 showing the Red Sea, Saudi Arabia and the Persian Gulf.

A comparison of the ITOS APT system and the TIROS-N APT system is shown in Table 6 below.

Table 6.

Comparison of ITOS and TIROS-N APT Systems

Parameter	ITOS APT	TIROS-N APT
• Line Rate	48 Lines/Minute	120 Lines/Minute
• Data Resolution	IR 7.4km Subpoint Visible 3.7km Subpoint	4km Uniform
• Carrier Modulation	Analog	Analog
• Transmit Frequency	137.50MHz 137.62MHz	137.50MHz 137.62MHz
• Transmit Power	5 Watts	5 Watts
• Transmit Antenna Polarization	Linear	Right Hand Circular
• Subcarrier Frequency	2.4KHz	2.4KHz
• Carrier Deviation	±9KHz	±17KHz
• Ground Station Low Pass Filter	Varies With Station & Use; 450-1600Hz in Use	1400Hz 7th Order Linear Recommended
• Synchronization	7 Pulses at 300Hz for Both Channels	7 Pulses at 1040Hz 50% Duty Cycle for Channel A; 7 Pulses at 832Hz, 60% Duty Cycle for Channel B

Figures 9 and 10 are examples of the TIROS-N APT capability. Figure 9 is a visible image and Figure 10 is an infrared image.

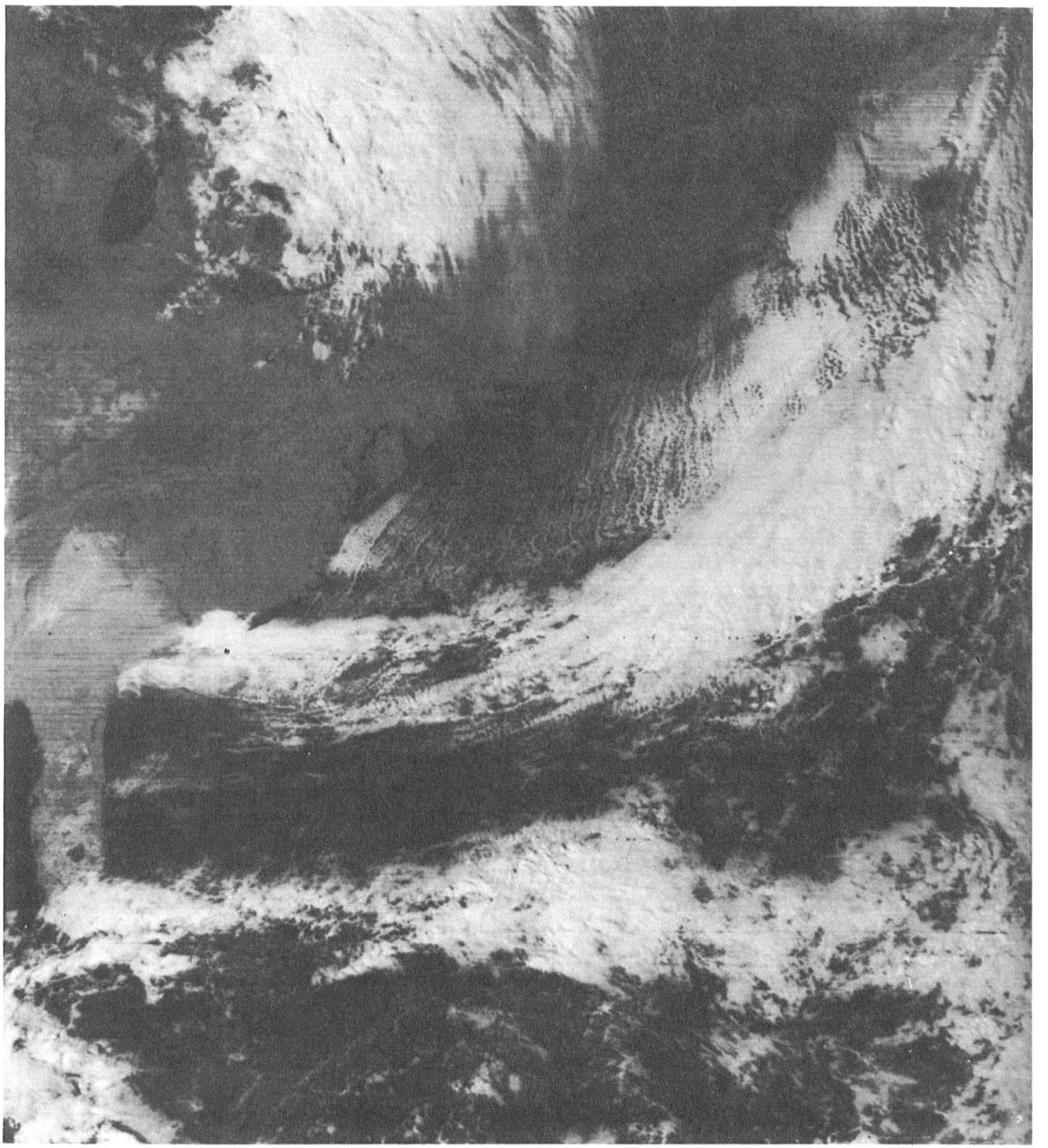


Figure 9. TIROS-N AVHRR APT visible image showing the eastern United States from Florida to Maine with a cold front located off the East Coast.

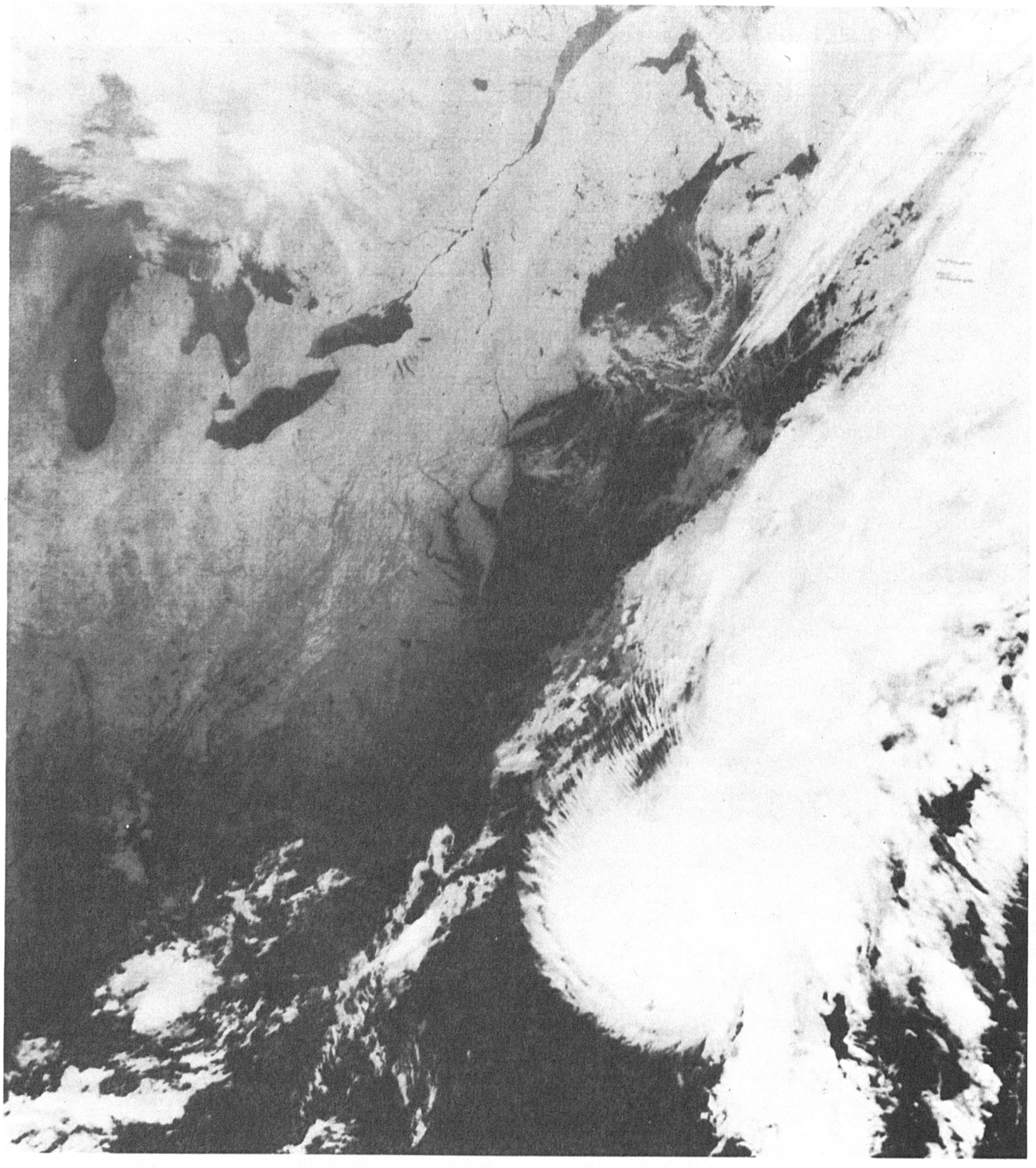


Figure 10. TIROS-N AVHRR APT infrared image taken on October 30, 1978 by the NASA Goddard Space Flight Center. It shows Hurricane Kendra which was held at sea by a large inland high pressure area as indicated by the clear area over the eastern U.S.

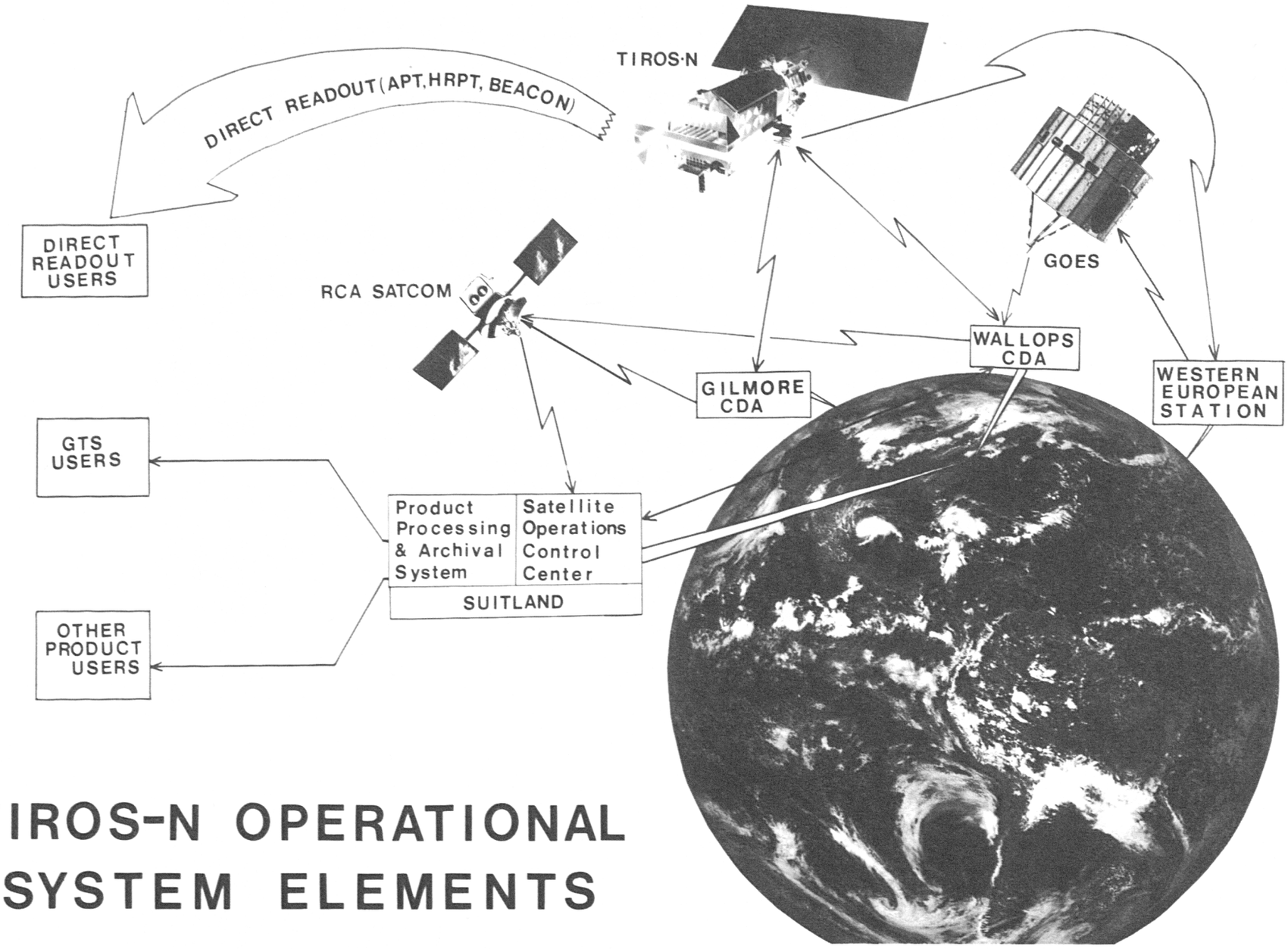
IV. TIROS-N/NOAA OPERATIONAL SYSTEM ELEMENTS

Figure 11 depicts the major elements of the TIROS-N/NOAA operational satellite system. The two primary NOAA Command and Data Acquisition (CDA) stations are located near Gilmore Creek, Alaska and Wallops Island, Virginia. The spacecraft programming and commanding originates at the NESS Satellite Operations Control Center (SOCC) located in Suitland, Maryland. The commands, spacecraft telemetry and environmental data are relayed between the SOCC and the CDA's via a commercial communications satellite, RCA's SATCOM in geostationary orbit at 119 degrees West longitude. This domestic satellite communications system, which includes recently installed RCA "earth stations" at Suitland and Wallops, delivers the data to the SOCC at 1.33 megabits per second. The CDA's communicate with the TIROS-N spacecraft using their S-Band links, and readout 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 Figure 12. 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 SOCC, at the Western European Station (WES) in Lannion, France, and at the Satellite Field Services Station (SFSS) in San Francisco. All the DPSS components are in the NOAA facility at Suitland.

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.

During three sequential orbits, and occasionally four on some days, the spacecraft is out of range of both NOAA CDA stations. To eliminate the resultant time delay in the receipt of the high priority sounding data during the "blind" period, a data readout station has been established at Lannion, France, as a joint venture of the United States and France. This station acquires the stored sounding data and transmits it to the United States, using the Data Collection System of the eastern GOES satellite located at 75 degrees West longitude. Use of this additional readout station reduces periods when the TIROS-N satellite is out of contact with the ground to a maximum of one orbit per day.



TIROS-N OPERATIONAL SYSTEM ELEMENTS

Figure 11.

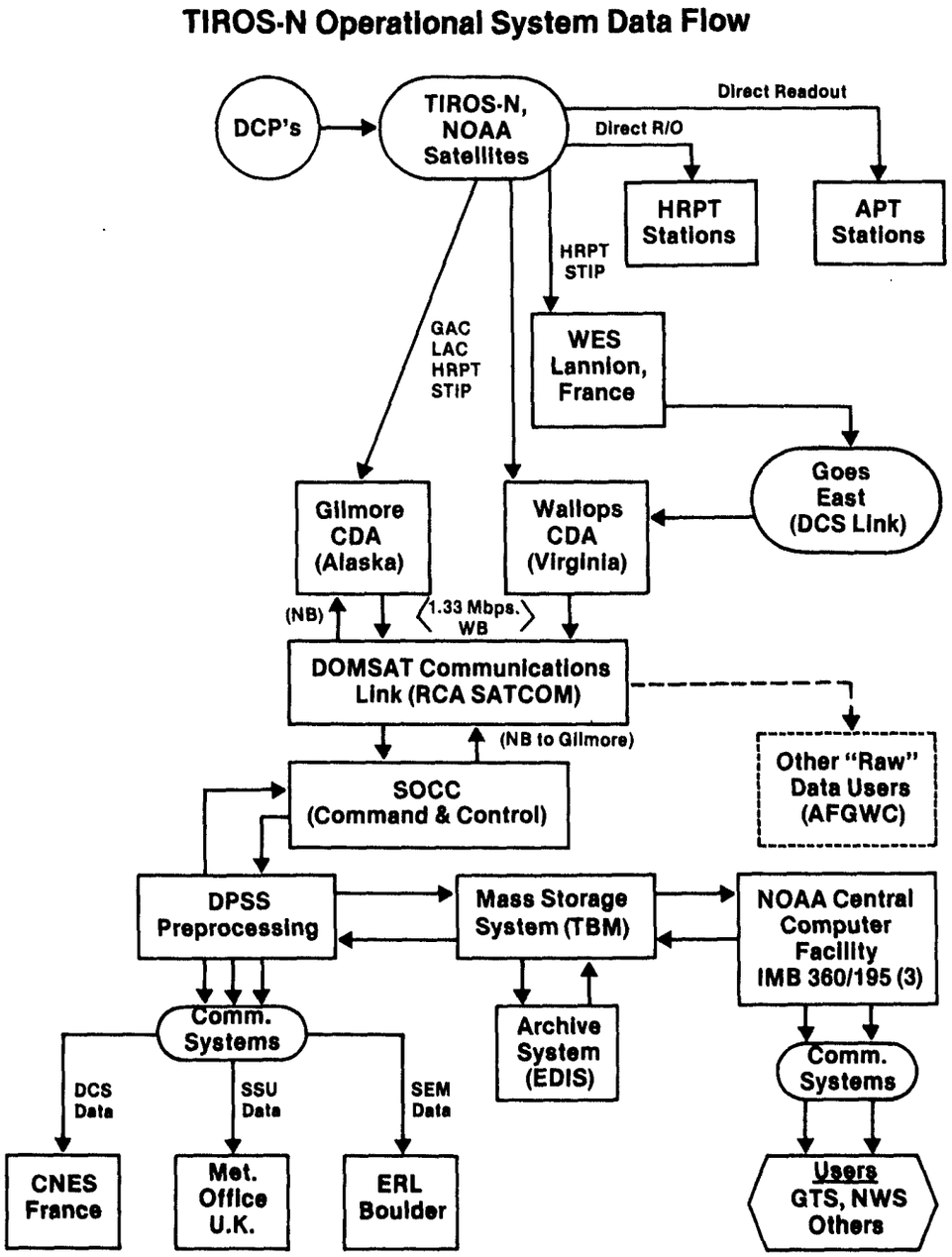


Figure 12. TIROS-N Operational System Data Flow Diagram

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 mass data storage system, called TBM II, has an on-line storage capacity equivalent to that of 1000 average computer tapes or 460 IBM 3330-type disc packs. Thus, all the data obtained from two TIROS-N type spacecraft for a 24-hour period can be stored on a single TBM II tape, which is archived by the Satellite Data Services Branch of NOAA's Environmental Data and Information Service (EDIS). The TBM II utilizes standard, two-inch-wide video tape. Rapid access to any record on the tape is achieved by performing address searches at tape speeds of 1000 inches per second, both forward and backward. Searching at such a high speed, coupled with up to six simultaneous accesses, is the equivalent of searching through 300 average computer tapes per second.

As has been previously discussed, the TIROS-N/NOAA satellites carry a variety of radiometric instruments that provide an extremely large volume of digital data for the derivation of quantitative and imagery products. NOAA has produced an initial set of sounding products, oceanographic and hydrologic products, heat budget products and an array of mapped/gridded imagery products. The products derived from the quantitative processing of digital radiometric measurements are processed in the NOAA Central Computer Facility at Suitland, Maryland on IBM 360/195 computers. The initial set of TIROS-N sounding products which are derived on a global basis and transmitted over the Global Telecommunications System (GTS) are listed in Table 7.

Table 7.

GTS Products From TIROS-N

Products	Accuracy Goals	WMO Code	Frequency
1. Thickness (M) Between Standard Pressure Levels	Equivalent to ±2.0°K	FM86-VI Ext. SATEM	14 Daily
2. Precipitable Water (MM) Between Standard Pressure Levels	±30%	FM86-VI Ext. SATEM	14 Daily
3. Tropopause Temp. (DEG.) and Pressure (MB)	±2.5°K ±50 MB	FM86-VI Ext. SATEM	14 Daily
4. Cloud Cover From Area of Soundings and Pressure at Average Cloud Height	±20%	FM86-VI Ext. SATEM	14 Daily
5. Clear Radiances (in Terms of Brightness Temperature, °K)	±2%	FM87-VII Ext. SARAD	14 Daily

The oceanographic and hydrologic products include sea surface temperature analyses on a regional and global scale, polar region ice coverage analyses, and snow and ice melting conditions. The heat budget products include global analyses of day and night longwave flux, reflected energy and available solar energy. The large array of image products includes hemispheric and mercator mapped mosiacs, minimum brightness/ maximum temperature polar composites and gridded pass-by-pass imagery in both the visible and infrared.

V. FUTURE OF THE TIROS-N/NOAA SATELLITE SYSTEM

The third generation TIROS-N/NOAA series of operational polar orbiting satellites is planned to provide for continuous global data coverage through 1985. TIROS-N was launched in October 1978 with the second spacecraft in the series NOAA-A scheduled for launch in May 1979.

A three-to-four week activation and evaluation period is reserved following the NOAA-A launch to perform engineering tests. Instruments will be operated during this period, but transmission of usable data will be sporadic at best. Neither the AVHRR nor the HIRS/2 instrument will be activated during the first two weeks following launch to allow for outgassing of contaminants from the spacecraft. For TIROS-N, the period of intermittent engineering evaluation extended for several weeks. Routine operational data from NOAA-A can be expected much sooner because the initial evaluation period will be shorter.

The TIROS-N type satellites have been designed to retain sufficient space, weight, and data handling capability so that additional instruments can be added later in the program without redesigning the entire satellite. Reserve capacity for payload growth is approximately 20 percent of the initial payload complement. Three new instrument payloads are currently planned to be incorporated within this growth capability:

- A Search and Rescue (SAR) system comprised of repeater and processor units.
- A Solar Backscatter Ultraviolet Radiometer (SBUV/2).
- Two Earth Radiation Budget Experiment (ERBE) instruments (a scanner and a non-scanner version).

The resulting new configuration of instrument payloads will be known as the Advanced TIROS-N (ATN) spacecraft. The ATN configuration will be incorporated on the last three spacecraft of this series; NOAA-E, -F, and -G. The SAR payload will be included on NOAA-E, -F, and -G and the ERBE will be included on NOAA-F and -G. Problems associated with the procurement of the SBUV/2 instrument make it uncertain at this time if it will be included on the last of the series, NOAA-G.

For the ATN, a modified elongated spacecraft bus design including an additional set of pinwheel thermal control louvers (for a total of 16) will be used. The planned launch weight of the ATN is 1693 kg. including the apogee motor, a 271 kg.

increase over the prototype TIROS-N spacecraft. An increase in the Reaction Support System low-level thrust to 100 pounds is planned as a consequence of the greater spacecraft mass; but no additional propellant capacity is planned. The basic instrument payload, with the exception of the five channel AVHRR/2 and the new instruments will remain essentially the same as those flown on TIROS-N.

The launches of TIROS-N and future NOAA operational spacecraft are illustrated in Figure 13. A total of eight spacecraft are planned for the TIROS-N series through 1985. To ensure an uninterrupted data flow and replacement of lost capabilities, later spacecraft will be launched as necessary on a callup basis when available. Initial planning has begun for the fourth generation of operational polar orbiting environmental satellites (called "System 85") to be ready by 1985 to continue the uninterrupted acquisition of data by remote sensing from space of the earth's atmosphere, its surface, and its near space.

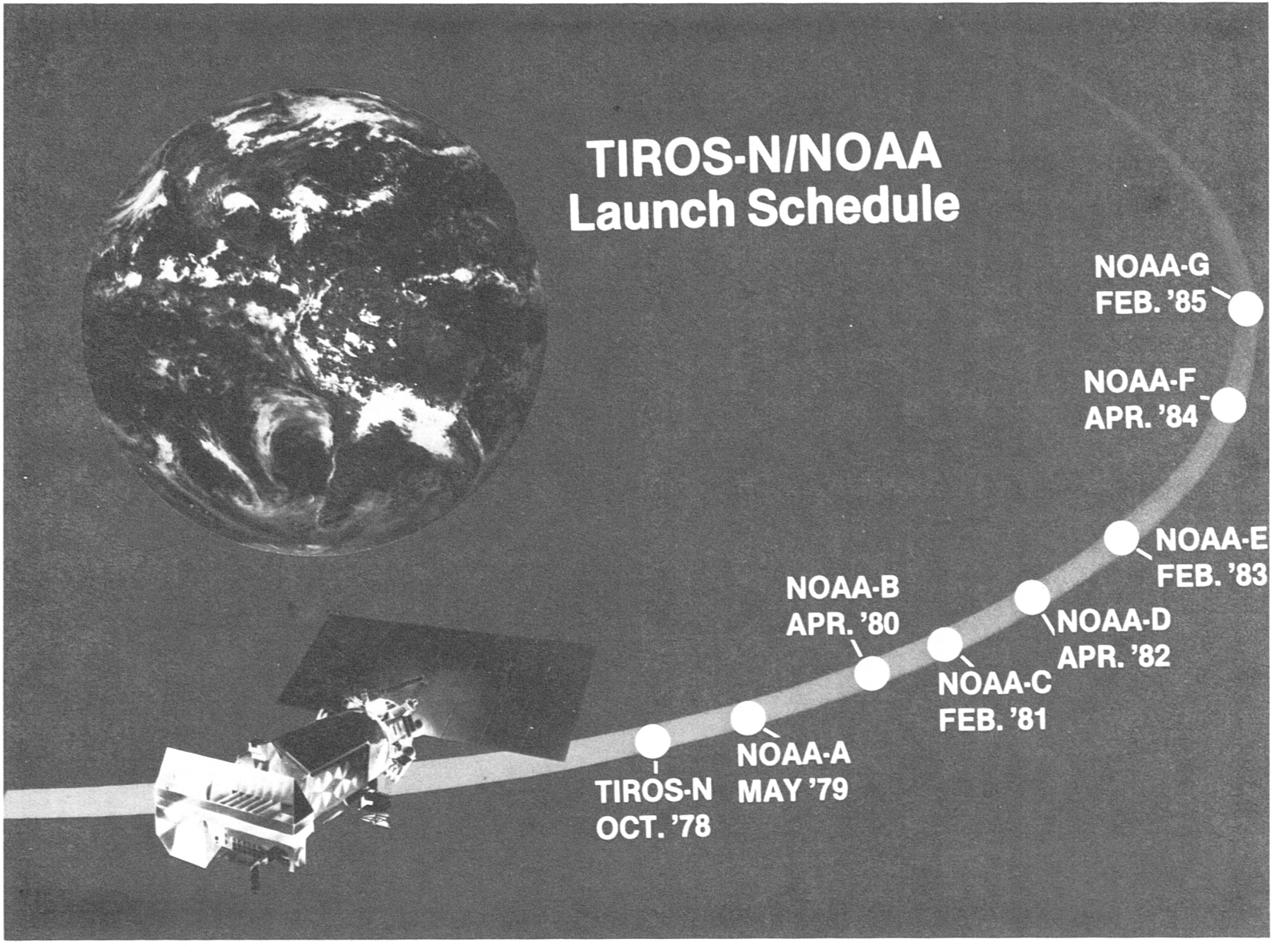


Figure 13. TIROS-N/NOAA Launch Schedule

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