U.S. DEPARTMENT OF COMMERCE / Environmental Science Services Administration

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SATELLITE ACTIVITIES OF ESSA-1968

compiled by the

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National Oceanic and Atmospheric Administration
TIROS Satellites and Satellite Meteorology

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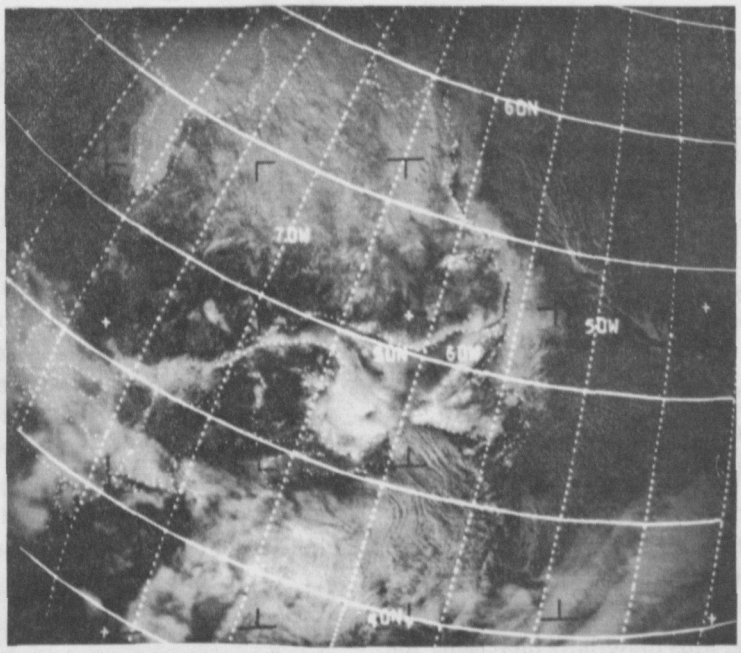

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The Environmental Science Services Administration fulfills the Department's responsibility to describe, understand, and predict the state of the atmosphere, the oceans and the space environment, and the size and shape of the Earth. ESSA has five major subunits which contribute either directly or indirectly to space technology: the National Environmental Satellite Center, the Weather Bureau, the Coast and Geodetic Survey, the ESSA Research Laboratories, and the Environmental Data Service.

Highlights of 1968—Two Environmental Survey Satellites—ESSA 7 and 8—were launched during 1968 to maintain the operational weather satellite system established in February 1966. April 1 marked the eighth anniversary of the launch of TIROS I, the first weather satellite to send back useable cloud pictures. The one-millionth satellite picture was received on May 27, 1968.

With the cooperation of NASA experimenters, ESSA used the ATS–III satellite to obtain closely timed pictures of both tornadoes and hurricanes. Films made from these pictures, taken every 15 minutes during periods of maximum lighting, were used to study details of the development and life cycles of these storms. Equipment has been designed to permit timely acquisition of these pictures for operational use.

The satellite-interrogated ocean buoy program was advanced by the successful test of a prototype moored in 14,500 feet of water at 35° N. 48° W. in the North Atlantic. After remaining on station successfully for 4 months, the mast broke during an unusually severe storm and the buoy was recovered. The test demonstrated the stability of the buoy and the durability of the mooring, which remained intact.

A special facsimile transmission was added to an established U.S. network to relay Automatic Picture Transmission photographs from receiving stations to 23 Weather Bureau and 28 military stations on the network. This relay of APT photos has greatly increased dissemination and operational use of satellite data.

The Weather Facsimile Experiment transmission of satellite and standard meteorological data from the United States to APT stations in Europe, Africa, and South America via the ATS III satellite started experimentally in July, and by October had become semi-operational. WEFAX transmissions to the Pacific via ATS–I continued during 1968. Response from recipients is enthusiastic.

Meteorological Satellites—The National Operational Meteorological Satellite System (NOMSS) was likewise maintained during 1968 by the launch of ESSA 7 and 8. These satellites furnished worldwide pictorial coverage of the Earth and its cloud systems daily, except in areas of polar night.

The ESSA series of satellites partially fulfills one of the main objectives of the NOMSS—daily observation of global weather conditions—but does not permit nighttime observations of cloud systems or temperature patterns. TIROS–M, the operational prototype of the ITOS (Improved TIROS Operational Satellite) sys-

tem satellites, will add a nighttime cloud surveillance and day-and-night temperature mapping capability by means of a scanning radiometer. This spacecraft also will combine the functions now performed separately by two ESSA satellites, with a consequent saving in costs because fewer launches will be required each year. The launch of the TIROS–M spacecraft, planned for the middle of Calendar Year 1969, will be followed by the launch of ITOS operational spacecraft starting late in 1969.

Operations of the ESSA Satellites—ESSA satellites orbit the Earth in about 114 minutes at average altitudes of 760 nautical miles.

One type of ESSA satellite is equipped with two Advanced Vidicon Camera System (AVCS) units, each of which is capable of maintaining global cloud-cover surveillance. One camera is used operationally; the second is held in reserve, thus materially increasing the useful lifetime of the satellites. The pictures from AVCS-equipped satellites are transmitted to ground stations in Alaska and Virginia, relayed to a central processing unit at Suitland, Md., processed, and made available to the United States and international meteorological community.

Equipment for the other type of ESSA satellite is also redundant; each of the two Automatic Picture Transmission (APT) cameras can take and immediately transmit pictures of the area beneath the satellite to simply equipped ground stations within a 2,000-mile range of the spacecraft. The APT pictures furnish local forecasters with a fresh (3½-minute-old) view of the cloud patterns over or adjacent to the local area; these are used widely by U.S. meteorological agencies. Meteorologists in many countries have become accustomed to using APT pictures for operational forecasting. Thus the APT-equipped satellites have become an integral part of the World Weather Watch, an international meteorological observation system now under development. Mosaics covering the United States and adjacent areas are prepared daily from APT pictures received at Suitland. Copies are distributed to local and national news services, and are used daily by many newspapers and television stations in the United States.

NIMBUS II—APT pictures from the NIMBUS II R. & D. satellite were used operationally until the system ceased functioning near the beginning of April 1968, more than 22 months after launch.

Applications Technology Satellites—APPLICATIONS TECHNOLOGY SATELLITES (ATS–I and ATS–III, launched respectively on Dec. 6, 1966, and Nov. 5, 1967, by NASA) have successfully demonstrated the potential of a geostationary satellite for environmental observation. Both satellites contain spin-scan cloud cameras which can take pictures approximately once every 20 minutes. ATS–I photographs the Pacific basin and ATS–III photographs the Atlantic. The ATS–III camera was designed for color photography, using three separate color channels. The system worked well for several months, but subsequent malfunction of the red channel has reduced ATS–III to essentially black-and-white photography. Details on the uses of these cameras and the transponders aboard these satellites are given elsewhere.

Computer-Processed Cloud Mosaics—Cloud photographs are processed routinely by computer for operational use; the pictures are digitized, rectified, and fit into global mosaics for routine transmission via facsimile to all U.S. Weather Stations. Some have been transmitted experimentally (and successfully) to APT stations in Europe, Asia, Australia, the Pacific Ocean area, and North and South America by means of transmitters on board the ATS satellites. Special mosaics of the tropics are sent to the National Hurricane and the Tropical Analysis Centers in Miami during the hurricane season. The mosaics are also printed in catalogues of cloud photography to make the information accessible to research scientists.

Operational Applications of Satellite data—Routine and reliable receipt of data from both types of ESSA spacecraft has resulted in widespread usage of satellite information in daily operations both in the United States and abroad. Data available are those centrally processed in the United States, and the pictures received locally from the satellites equipped with Automatic Picture Transmission cameras. APT photographs are used operationally for analyses, local and area forecasts, and for briefing pilots on weather conditions over long transocean routes.

Satellite photography is particularly useful for tracking weather systems across the vast areas of Earth where conventional observations are lacking. The most spectacular use is in the discovery and tracking of tropical storms, typhoons, and hurricanes wherever they may occur. During 1968, 33 of these storms had been seen

by the satellites, and advisories had been sent to foreign countries and U.S. installations worldwide. A method devised for estimating maximum winds in these tropical storms from characteristics seen in the satelitte pictures has been used successfully for several years. Tracking of storms in middle and high altitudes has resulted in improved advisory service to coastal areas and to shipping on the high seas.

Winds in the 30,000–40,000-foot levels as estimated from ESSA photographs are used routinely in computer analyses, and are transmitted daily to users worldwide. These experimental winds provide information over tropical and subtropical areas that are almost completely devoid of conventional upper-level wind information.

Research and development programs of the National Environmental Satellite Center—In 1968 work continued on a number of long-term projects, and was initiated on several new projects. The research included studies to increase basic understanding of atmospheric processes, the objectives of which are to improve weather analysis and forecasting; the development of new instrumentation for measuring environmental data from satellites; and the development of new methods and procedures for using satellite data in daily operations. Among the more than 50 investigations under way, the following are of particular interest:

a. A number of instruments are being designed to obtain measurements of the vertical structure of the atmosphere. The Satellite Infrared Spectrometer (SIRS), developed by NESC and funded by NASA, is to be tested on NIMBUS B2, scheduled for launch by the middle of 1969. The Infrared Temperature Profile Radiometer, an adaptation of SIRS, is under development for testing on NIMBUS E. This instrument has a spatial scanning capability to permit operation over partly cloudy skies.

b. Procedures for obtaining the extent and depth of snow fields from satellite pictures are being investigated. An operational guide for mapping the extent of snow cover was developed under an NESC contract in 1968. Large-scale mapping of snow cover and sea ice by means of satellite pictures is being done experimentally.

c. Procedures developed for making time-lapse motion picture film from ATS–I and ATS–III photographs have enabled research meteorologists to study details of tornado and hurricane development. The ATS pictures, available at either 15-, 24- or 30-minute intervals, provide views of these storm systems heretofore unavailable. A major research effort is being directed toward devising more efficient and timely methods for the extraction of multilevel wind information from the ATS spin-scan cloud camera pictures and films.

d. Digitized daily records of cloud data are being used to supply various products such as average 5-day, monthly, and seasonal cloud charts, and brightness charts. Films of the daily digitized charts show broad-scale motions in both the tropics and mid-latitudes, and show climatic regimes in a graphic fashion. These charts and films are proving useful for heat-balance studies, radiation studies, ice mapping, and long-period variations in large-scale weather features; they also show promise of being useful for developing improved global cloud climatologies.

e. Plans are under way for intensive investigations of the ocean surface, the interactions between the sea and the atmosphere, and the temperature structure of the ocean by means of satellite sensors. The state of sea surface is being estimated by analysis of reflection of the Sun seen in satellite pictures; analyses such as these will yield estimates of surface wind speeds in remote areas. Temperature fields and ocean currents will be mapped and the information used in meteorological and oceanographic investigations.

International Cooperation—The continued worldwide availability of Automatic Picture Transmission (APT) pictures and the experimental semi-operational transmission of satellite data through the Weather Facsimile Experiment (WEFAX) on the ATS satellites has helped to maintain the image of the United States as an unstinting sharer of scientific results in space programs. At the end of 1968, 52 foreign countries reported 108 APT stations in operation. Application of satellite products was discussed and demonstrated daily by United States participants at the International Conference on the Peaceful Uses of Space in Vienna. Current and planned satellite products were also discussed at the International Cloud Physics Conference in To-

ronto and at the International Union of Geodesy and Geophysics—World Meteorological Organization (IUGG–WMO) meetings in Bergen, Norway, during August 1968. U.S. participants furnished major contributions to the WMO satellite meteorology workshop held in Melbourne, Australia, during November and December 1968. The National Environmental Satellite Center provided training and study facilities for WMO, NATO, and AID fellows from China, Greece, Hungary, India, Indonesia, the Philippines, Switzerland, and Thailand, and briefings for many other foreign scientists during 1968.

Washington-Moscow Data Exchange—Pursuant to the 1962 bilateral agreement between the United States and the U.S.S.R., exchange of satellite data continued over the Washington-Moscow data link during 1968. The U.S.S.R. furnished data from their COSMOS 184, launched in 1967, and COSMOS 206 and 226, launched in 1968. The United States furnished satellite photographs and nephanalyses (cloud maps) based on ESSA 3, 5, and 7 data; these products are used in daily analysis operations at the World Weather Center, Moscow. Traffic from Moscow includes satellite photographs, nephanalyses, and radiation analyses.

ESSA Research Laboratories

The ESSA Research Laboratories, with main offices in Boulder, Colo., and a number of Laboratories in field stations elsewhere, conduct research and provide services in support of the broad ESSA mission requirements. Activities include a number of scientic disciplines: oceanography, Earth sciences, geomagnetism, tropospheric and ionospheric and magnetospheric physics. Programs include tropospheric radio and optical wave propagation, ionospheric radio propagation, monitoring and forecasting solar activity and its effects in Earth's vicinity, and research on solar radiation interactions with the magnetosphere.

The ERL Space Disturbance Laboratory monitors and predicts fluctuations and disturbances in Earth's space environment associated with solar activity. Research activities support these services and increase understanding of the manner in which solar particles affect Earth's environment.

A facility at Anchorage, Alaska, is now operational as part of the Space Disturbance Forecasting Center. This facility is a center for a net of stations used to detect the precipitation of solar protons into the high atmosphere in the Arctic region.

Solar X-ray data are obtained on a timely basis from the SOLAR RADIATION SATELLITE, SOLRAD 9, for use in making disturbance forecasts. Data are obtained with the cooperation of the Naval Research Laboratories.

In cooperation with Canadian scientists, SKUA rockets intrumented to monitor radiation in the 1.27×10^{-3} millimeter wave length range, are used to obtain measurements of the diurnal variations and height profiles of molecular oxygen in the excited state. Several successful flights have been made from Fort Churchill, Canada, and data obtained are being analyzed. These results are important in understanding the electron balance of the lower ionosphere.

Auroral zone absorption events observed from the Earth's surface are compared with energetic particle observations obtained by NASA satellites while passing through the tail of the Earth's magnetosphere at about 17 Earth radii. These comparisons indicate that the particle source producing the absorption is relatively close to the Earth.

A preliminary study has established the feasibility of providing forecasts of solar activity for the APOLLO Applications Program-Astronomical Telescope Mount (AAP-ATM) program. The aims of this program are to supply to the ATM astronauts forecasts of the probabilities of occurrence and probable location of solar flares so that high-resolution instruments can be activated and properly oriented to obtain measurements. The Space Disturbance Forecasting Center will also collect and disseminate solar data for use during postflight analyses of data obtained in the ATM program.

The ERL Aeronomy Laboratory conducts research on the ionosphere and the magnetosphere. The Laboratory operates, in cooperation with Peruvian scientists, a facility using radio techniques based on the scattering of radio waves by electrons to obtain measurements of the high ionospheric region. Recently, the technique has been used to measure electric fields in the high ionosphere, measurements previously obtained at great expense and for short time periods only, by rockets. The current method is based on monitoring the vertical

electron drift in the ionosphere and makes possible continuous studies from a ground facility. This station also makes measurements of ionospheric parameters, such as electron and neutral temperatures. In some cases, comparisons between these measurements and those obtained by satellites show significant discrepancies. Since other evidence indicates that the scatter results obtained from the ground are accurate, the uncertainties may be associated with the satellite measurements.

Ultraviolet data from the NRL SOLRAD satellites are monitored during periods of atmospheric occultation and analyzed to obtain oxygen density in the vicinity of 62 miles. The results show that summer densities are about 1.5 larger than winter densities.

Theoretical studies were undertaken which successfully explain the ionospheric resonances observed by satellite radio sounders. This theoretical development, which involves echoes from the plasma in the near field of the antenna, explains certain aspects of these resonances, which have been difficult to explain by previous theory.

Part of the Aeronomy Laboratory rocket program is conducted in cooperation with the rocket program of the Space Disturbances Laboratory. The rockets are instrumented to obtain the electron density in the ionosphere by means of radio signals transmitted from the rocket using Faraday rotation techniques.

A method for obtaining atomic oxygen measurements by using thin films of silver has been developed for use on rockets. These thin films, exposed to the atmosphere during the rocket's flight, produce silver oxide, thereby changing the electrical resistance. The data thus obtained yield atomic oxygen profiles.

Data obtained from the ALOUETTE I and II topside sounders and the earlier EXPLORER XX are analyzed to determine the effects of magnetic storms on ionospheric electron density. A new method developed this year provides electron density and temperature profiles from topside sounder data more precisely than in the past.

Further theoretical developments on the effects of electric charge on satellite probes have increased accuracies of data from these probes. This theory takes into account effects such as secondary emission produced by photons and the contamination in the emission from energetic particles.

Magnetic storms and subvisual optical emissions, known as red arcs, are studied by comparing simultaneous data from several satellite electron-density measurements with ground-based optical experiments. These analyses show that the electron density within the arc is less than that outside the arc. These studies are expected to lead to an explanation of the red arc and other ionospheric effects.

The Tropospheric Telecommunications Laboratory conducts studies to develop and improve communications by means of satellites. The operational use of satellites for air traffic control is under consideration to help alleviate overcrowding of radio frequency bands currently in use. One objective is to define interference protection ratios required to maintain adequate intelligibility over communications circuits. Air traffic control transmissions are simulated, using conventional circuits under varying conditions. Both subjective and objective evaluations of the transmissions are made.

Communications and telemetry with satellites sometimes suffer interference by scatter of signals from other communications links which are precipitated into the satellite acquisition systems. A program to analyze this problem has been undertaken; computations have been made of precipitation scatter, relating levels of received power to probability of occurrence.

Electromagnetic wave devices used for tracking objects in space and for measuring geodetic distances and angles have accuracies which are limited by the time-space variation of radio or optical refraction. Measurements of refraction effects taken in Colorado and in Hawaii are being used to study the correlation of range and angular position errors with refractive-index data obtained from a variety of sensing elements. These studies will improve accuracy in geodetic measurements and missile tracking.

Another approach to this problem is being studied by the Wave Propagation Laboratory. This laboratory has used radiometers to measure the emissivities of atmospheric water in its various forms at several frequencies in the millimeter wave region. The measurements were made together with periodic meteorological observations and observations by the Tropospheric Telecommunications Laboratories of radio phase path.

Since the accuracy of radar tracking of missiles, satellites, and other objects is limited by these effects, comparative analysis of the various observations may yield a new method, employing radiometry, to improve tracking accuracy. The data will also be analyzed to establish the effects of atmospheric water on satellite remote sensing in the millimeter wave region.

Satellite photographs are used by the Atlantic Oceanographic Laboratories in the study of low-level convective cloud patterns in the eastern Caribbean and western tropical Atlantic Ocean. These patterns will be related to observations of temperature, pressure, wind and other meteorological parameters obtained during the Barbados experiments. Ocean thermal data obtained by the ESSA research vessels in the vicinity of the Gulf Stream will be correlated with high-resolution infrared radiation data from NIMBUS II.

The Air Resources Laboratory has established microphone networks for measurements of sonic booms from supersonic aircraft. These measurements will be correlated with meteorological data and with aircraft flight configurations.

Coast And Geodetic Survey Operations

The Coast and Geodetic Survey uses satellites operationally in geodesy and precise navigation; is engaged in studies to determine the feasibility of using satellite techniques in performing its assigned tasks; and supports space facilities and activities indirectly through its seismic and geomagnetic activities.

Geometric Satellite Triangulation—The Coast and Geodetic Survey's Geodetic Research Laboratory devoted most of its 1968 activity to support the worldwide Geometric Satellite Triangulation Program being conducted under a cooperative agreement between the Department of Commerce and the Department of Defense. The Laboratory provided technical and scientific support in the areas of data acquisition, laboratory measurements of field records, data reduction procedures and data analysis.

Preliminary results obtained at 25 stations of the worldwide network and from about 350 events indicate that the eventual goal of an accuracy of about ±20 feet in latitude and longitude and 33 feet in height at each station is feasible.

Satellite triangulation computer programs have been revised to provide improved statistical analysis, to eliminate inconsistencies in the raw data, to incorporate range data and to handle fully correlated observations.

The BC-4 camera data, totalling about 150,000 individual directions, have been sent to the NASA Geodetic Data Library. Aggregated reduced directions have been provided to the Smithsonian Astrophysical Observatory.

A series of studies on the need for additional scale measurements in the worldwide network resulted in the conclusion that five such measurements are desirable.

The long-range and high-precision short-range orbit-prediction computer programs for balloon satellites were improved and refined by introducing a flexible gravitational model into the former and a theoretical model to account for solar radiation pressure into the latter. Resonance theory was applied to PAGEOS geodetic satellite orbit to extract numerical values for resonant gravitational harmonics.

A project is under way for determining the high-frequency variations of Earth's gravitational field by applying a surface density layer instead of spherical harmonics. This will bypass the problem of convergence in the latter mathematical representation.

The Satellite Triangulation Division continued data acquisition providing technical supervision for 15 geodetic camera units throughout the world. Eight systems are operated by the Coast and Geodetic Survey, four by the Army Map Service, and one, owned by West Germany, is operated jointly with the Coast and Geodetic Survey. The Survey also operates one system with the United Kingdom and another with South Africa. Thirty-four of the 43 proposed stations have been or are presently occupied.

Time Transfer Tests—The Satellite Triangulation Division together with the National Bureau of Standards and NASA continued tests on transferring time via NASA's APPLICATIONS TECHNOLOGY SATELLITES, ATS I and III, to isolated stations in various parts of the world. Accuracies of ±2 microseconds are now being achieved. This method is now used to transfer time to Tristan da Cunha, South Georgia, and Villa Dolores, Argentina.

A Time Recovery Receiver has been developed to check and establish precise time on five isolated Antarctic stations. Since the range of ATS satellites is not sufficient to reach the Antarctic, U.S. Navy TRANSIT satellites must be used. The result is an accuracy of 50 microseconds.

Earth Resources Program—In connection with NASA's Geodetic-Cartographic sub-program, studies continued on the application of space technology to the Earth Resources Program. Emphasis was placed on the definition of and the specifications for a photogrametric space system for the establishment of geodetic control and determination of the geometric shape of Earth's ocean surfaces. The photogrammetric system consists of two wide-angle mapping cameras, two panoramic cameras, two stellar cameras and a laser or radar altimeter, all in a single rigid package or mount. The C. & G.S. contracted with NASA to be responsible for aircraft flight tests of a camera-laser package for the evaluation of a NASA-developed laser altimeter which is nearing completion.

Activities in Support of the Tsunami Warning System—Continued efforts are being made to improve the operation of the Coast and Geodetic Survey's Tsunami Warning System through faster communications and data telemetry. An experiment is planned for 1969 in which sea-level data will be transmitted via the NASA ATS-III satellite from an underwater platform near Andros Island, in the Bahamas, to NASA's Goddard Space Flight Center.

Seismological Activities—The Coast and Geodetic Survey's Seismology Division has done a series of seismic measurements from propellant explosions to assess potential damage from rockets during launch operations. A report on the results of monitoring 12 intentional explosions of rocket propellants has been submitted to NASA's Advanced Studies Office at the Kennedy Space Center.

The conclusions of this study are:

1. For rocket detonations, the TNT equivalence determined by seismic techniques in the far field (beyond 1,000 feet) area ranged from a low 0.2% for 25,000 pounds of a mixture of liquid oxygen and liquid hydrogen confined by missile failure, to 22% for a solid-propellant explosion with a charge equivalent to 7,000 pounds of TNT.

2. The variation of propellant type, mode of failure, or propellant weight did not produce a statistically significant TNT equivalence for the tests monitored.

3. There were sufficient data to establish a statistical rate of decay of the acoustic signal through the distance range of 2,000 to 10,000 feet.

While there was sufficient evidence to indicate a TNT equivalence of liquid propellants approaching 10%, it was pointed out that there is no assurance that the conditions for maximum efficiency of the propellant explosion were actually met. Therefore, it may be possible to have a rocket detonation with an efficiency greater than 10%.

Among the recommendations included in this report was a call for continuance of the seismic monitoring program in the areas of potential damage during the launch of larger missiles.

Geomagnetism—ESSA's Fredericksburg Geomagnetic Center continued to make calibration and test facilities and services available to NASA as a contribution toward the development of space instrumentation. A 19th century Swiss-made theodolite, having a large, calibrated circle of very high quality, was renovated and modified by the Center for use in accurately aligning space sensors.

All magnetic survey data collected from world-wide sources were screened and evaluated by C. & G.S. These data were used in a continuing, cooperative effort to improve knowledge and understanding of the characteristics and behavior of Earth's magnetic field. These studies proceed through the development of accurate mathematical models of the magnetic field from surface levels to satellite altitudes.

C. & G.S. personnel assisted the World Magnetic Survey Board of the International Union of Geodesy and Geophysics in preparing for an international Symposium, to be held in Washington, on "Description of the Earth's Magnetic Field."

Weather Bureau Operations

The rapid gains made in 1967 by the Weather Bureau in participation in the space program have been consolidated during 1968. Experiments are continuing in data relay, with plans to include test collection of data

from ships at sea. Implementation of specific programs for increased operational utilization of satellite data has been intensified, notably in tropical storm forecasting. The Bureau is also providing greater support to various satellite programs both directly and indirectly.

Experiment With ATS–1 Satellite—Experiments in data collection and relay of river stage and rainfall measurements are being continued by the Weather Bureau's Office of Hydrology using NASA's ATS–1 geostationary satellite. Operational experience accumulated from this experiment will furnish a basis for effective planning of future systems.

Experiment With ATS–3 Satellite—The Weather Bureau is providing support for the ATS WEFAX (Weather Facsimile) experiment by having JFK—New York, Miami, New Orleans, and San Juan receive the WEFAX transmissions and submit evaluations of these to National Environmental Satellite Center.

Snow Surveying—Under a contract effort, an "Operational Guide for Mapping Snow Cover from Satellite Photographs" has been developed for the plains areas of the United States. Work is now progressing on developing techniques for mapping snow cover in the mountain States of the West. TIROS and ESSA photographs of the snow cover in the western States are being used in experimental support of the Weather Bureau's River and Flood Forecasting Service.

Sensor Study—A sensor evaluation study is being made under contract to ascertain what satellite sensors hold the most promise of providing useful data in meeting problems confronting the Weather Bureau's hydrologic mission. Results of this study will be used as input to planning the applications of space-derived data to hydrology.

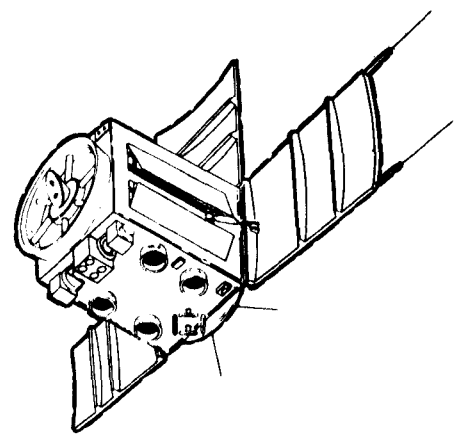
Digitized Cloud Mosaics—The operational program for facsimile transmission of digitalized mosaics has been expanded to provide information not only to the 50 States and Puerto Rico but also to the U.S. Air Force and Navy to fulfill their special requirements.

Automatic Picture Transmission (APT)—Early in 1968 the Weather Bureau began the transmission of raw APT signals interspersed with conventional meteorological charts on a central facsimile network. The APT data are acquired by NESC at Wallops Island, Va., the Weather Bureau at San Francisco, and the Air Force at Kunia, Hawaii, and are relayed through Honolulu to San Francisco by cable.

Meteorological Support—The Space Operations Support Division of the Weather Bureau continued to furnish meteorological services to NASA in support of the manned spaceflight program, including the forecasting of weather and sea conditions for the APOLLO 7 and APOLLO 8 flights. This division furnishes a continuous weather observing and forecasting service in support of activity at Cape Kennedy, supplies specialized forecasts and meteorological support for test and development activities at NASA's Manned Spacecraft Center and Mississippi Test Facility, and develops special studies on weather and climate conditions affecting both space and aeronautical activities of NASA.

The Environmental Data Service

The Environmental Data Service, a major sub-unit of ESSA, archives satellite data after they have been used operationally. Both raw and processed data are placed in the archives of the National Weather Records Center (NWRC), which provides retrieval services for research scientists. Since satellite data are used most frequently in conjunction with other meteorological data, NWRC serves as a convenient one-stop outlet for the users. Government and private-sector scientists, universities, and industry can purchase, at cost, copies of the data in film, picture, or magnetic tape form. Data catalogs are published to provide customers a means to identify the particular items desired. Over 2,800 reels of data were furnished to users in 1968.



Some Satellites related to ESSA programs

GEODESY

Date	Name	Launch vehicle	Remarks
Oct. 31, 1962	Anna 1B	Thor-Able Star	Used three independent measuring techniques: Doppler frequency shift, flashing lights, and radio triangulation.
Jan. 11, 1964	Secor I	Thor-Agena D	Uses radio triangulation and trilateration.
Oct. 10, 1964	Beacon-Explorer XXII	Scout	Conducted reflecting-light geodetic measurements.
Mar. 9, 1965	Secor III	Thor-Agena D	
Mar. 11, 1965	Secor II	Thor-Able Star	
Apr. 3, 1965	Secor IV	Atlas-Agena D	
Apr. 29, 1965	Beacon-Explorer XXVII	Scout	
Aug. 10, 1965	Secor V	Scout	
Nov. 6, 1965	GEOS–I Explorer XXIX	Thor-Delta	
June 9, 1966	Secor VI	Atlas-Agena D	
June 23, 1966	Pageos I	Thor-Agena D	Spacecraft is a 100-foot-diameter balloon used as a photographic target to make geodetic measurements.
Aug. 19, 1966	Secor VII	Atlas-Agena D	
Oct. 5, 1966	Secor VIII	Atlas-Agena D	
June 29, 1967	Secor IX	Thor-Burner II	
Jan. 11, 1968	GEOS II	Thor-Delta	

WEATHER OBSERVATION

Apr. 1, 1960	Tiros I	Thor Able	First weather satellite providing cloud-cover photography.
Nov. 23, 1960	Tiros II	Thor-Delta	
July 12, 1961	Tiros III	Thor-Delta	
Feb. 8, 1962	Tiros IV	Thor-Delta	
June 19, 1962	Tiros V	Thor-Delta	
Sept. 18, 1962	Tiros VI	Thor-Delta	
June 19, 1963	Tiros VII	Thor-Delta	
Dec. 21, 1963	Tiros VIII	Thor-Delta	First weather satellite designed to transmit continuously local cloud conditions to ground stations equipped with APT receivers.
Aug. 28, 1964	Nimbus I	Thor-Agena B	Carried Advanced Videcon Camera System, APT, and a high-resolution infrared radiometer for night pictures.
Jan. 22, 1965	Tiros IX	Thor-Delta	First weather satellite in a Sun-synchronous orbit.
July 2, 1965	Tiros X	Thor-Delta	
Feb. 3, 1966	ESSA I	Thor-Delta	First operational weather satellite; carried two wide-angle TV camera systems.
Feb. 28, 1966	ESSA II	Thor-Delta	Complemented ESSA I with two wide-angle APT cameras.
May 15, 1966	Nimbus II	Thor-Agena B	
Oct. 2, 1966	ESSA III	Thor-Delta	Odd-numbered ESSA spacecraft carry two Advanced Videcon Camera Systems. Even-numbered spacecraft carry two Automatic Picture Transmission camera systems.
Dec. 6, 1966	ATS–1	Atlas-Agena D	Provided continuous black-and-white cloud-cover pictures from a synchronous orbit, using a Soumi camera system.
Jan. 26, 1967	ESSA IV	Thor-Delta	
Apr. 20, 1967	ESSA V	Thor-Delta	
Nov. 5, 1967	ATS–3	Atlas-Agena D	Provided continuous color cloud-cover pictures from a synchronous orbit, using three Soumi camera systems.
Nov. 10, 1967	ESSA VI	Thor-Delta	
Aug. 16, 1968	ESSA VII	Thor-Delta	
Dec. 15, 1968	ESSA VIII	Thor-Delta	