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PROJECT: NIMBUS-E

contents

NEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C. 20546

Joseph J. McRoberts
(Phone: 202/755-3680)

James F. Lynch (GSFC)
(Phone: 301/982-6255)

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ATMOSPHERE, OCEAN AND SURFACE MONITORING SATELLITE TO BE LAUNCHED BY NASA

A satellite which will take the first vertical temperature readings from space through clouds, monitor a mysterious disappearing current off the west coast of South America and thermally map the earth's surface so geologists can better understand what is happening below the crust, will be launched soon by the National Aeronautics and Space Administration.

Nimbus-E (Nimbus-5 in orbit), named after the Latin word for rain cloud, will be launched by the NASA no earlier than December 12 from the Western Test Range near Lompoc, Calif. A two stage Delta rocket will place the "butterfly"-shaped observatory into a near polar, circular orbit 1,103 Km (686 statute miles) high.

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November 29, 1972

The 772 kilograms (1,695 pounds) applications spacecraft, heaviest yet in the Nimbus series, will carry six advanced instruments or sensors -- three improved sensors similar to those aboard earlier Nimbus spacecraft and three brand new ones. These experimental sensors, designed to improve man's knowledge of his environment for the benefit of all mankind, will make the most precise measurements yet from space of the oceans, atmosphere and the earth's surface. Measurements of the entire globe will be made twice in every 24-hour period, once in sunlight (about local noon) and once again in darkness (about midnight).

"The ability to make vertical temperature and water vapor measurements of our planet's atmosphere for the first time through clouds is truly a giant step forward in meteorological research," said Dr. William Nordberg, Project Scientist from NASA's Goddard Space Flight Center, Greenbelt, Md. "Many parts of the world are under cloud cover more than 50 percent of the time. But now, with the microwave instruments aboard Nimbus-E, we will be able to penetrate most clouds. Precise temperature readings will be a great help to meteorologists for helping to improve weather forecast over long periods.

"The data from the microwave instruments will also be helpful to ships operating in the Arctic and Antarctic regions," said Dr. Nordberg. "Thin clouds, such as cirrus and stratus which are predominate in the polar regions, are relatively transparent in the microwave portion of the electromagnetic spectrum. We plan to map surface ice and water with the microwave sensors aboard Nimbus-E and we might even be able to differentiate between the old and more recently formed ice," Dr. Nordberg said.

Sensors aboard Nimbus-E will also map the Gulf Stream off the East Coast of the United States and the Humboldt Current off the West Coast of South America.

The Gulf stream meanders up to 81 km (50 miles) from Cape Hatteras, N.C., to Florida. Infrared sensors aboard Nimbus-E will plot the stream's daily position for the Navy's Fleet Weather Service. By knowing the stream's specific location each day, southbound ships will try to avoid it while northbound ships will ride in the stream receiving a few extra "bonus" knots per hour. Substantial savings can be realized by shipping interests by knowing the location of the stream on a daily, routine basis.

Changes in the Humboldt Current off the West Coast of South America have puzzled oceanographers for years. One major change now underway and causing great economic damage is called El Nino. The change begins around December with a movement of warm equatorial water south. The coastal waters warm up. This causes the nutrient-bearing cooler waters of the Humboldt Current, which normally control the weather, to disappear. As a result, the fish also disappear along with marine birds whose droppings provide a major fertilizer export called guano. Even crops along the coast are washed away from the heavy rains and flooding that accompanies El Nino.

The last severe El Nino was in 1957-58, however there have been minor ones in 1953, '63, '66 and '69. Scientists fear the one now believed to be slowly forming may be another severe one.

Nimbus-E may be able to provide valuable scientific data on causes of El Nino which would include sea surface temperature measurement, vertical atmospheric temperature profiles and cloud distribution.

Nimbus-E also carries an earth resources experiment, technically named Surface Composition Mapping Radiometer (SCMR). This versatile experiment will provide new information in the fields of geology, hydrology, agronomy, oceanography and meteorology. The instrument will measure the temperature of the earth's crust twice daily (about noon and midnight). The data from this experiment is especially attractive to geologists because by observing the change in temperature throughout the day, one can infer what is happening below the earth's surface.

Six highly advanced meteorological and earth resources experiments are aboard the Nimbus-E spacecraft. They are:

Electrically Scanning Microwave Radiometer (ESMR)
Infrared Temperature Profile Radiometer (ITPR)
Nimbus-E Microwave Spectrometer (NEMS)
Surface Composition Mapping Radiometer (SCMR)
Selective Chopper Radiometer (SCR)
Temperature Humidity Infrared Radiometer (THIR)

This is the first flight for the ESMR, NEMS, ITPR and SCMR aboard a Nimbus spacecraft. The SCR and THIR are improved versions of instruments which have flown on earlier Nimbus missions.

For the first time from space two of the instruments (ESMR and NEMS) will utilize the spectrum's microwave region for remote sensing. Some clouds, such as cirrus and stratus, are relatively transparent in the microwave region, but opaque in the infrared. Thus, the two sensors are expected to greatly increase the observatory's capabilities during many cloudy days.

The ESMR will globally map the thermal radiation emitted by the earth's surface and by the atmosphere. The measured absolute intensity of this radiation and, in particular, the mapped radiation patterns reflect a number of important physical properties of the surface and meteorological conditions in the atmosphere. Over water, temperatures measured by the satellite will vary widely depending primarily on the thickness and liquid water content of the overlying clouds. Heavy rain clouds, which may be indistinguishable in the visible or infrared from cirrus or stratus clouds containing little liquid water, will be easily identified and tracked at this wavelength.

The ITPR will measure the earth's terrestrial and atmosphere radiation in seven spectral bands. One of the bands will be used to determine earth surface temperatures in the absence of clouds or cloud top temperatures.

The NEMS will demonstrate the capabilities of microwave sensors for measuring tropospheric temperature profiles, water vapor abundance and water content of clouds even in the presence of many cloud types which block infrared sensors. Although infrared sensors readily probe cloud-free regions, large sections of the globe are frequently blanketed by cirrus or other clouds. Microwave sensors have most of the advantages of infrared sensors, but are much less sensitive to clouds. Thus, they have the potential of providing temperature profile information, water vapor abundance and cloud water content on a global scale under most meteorological conditions.

The SCR observes global temperature structure of the atmosphere at altitudes from cloud tops up to 50 kilometers (31 statute miles). The radiometer allows temperature to be taken along a strip 11 kilometers (7 statute miles) long in the direction of flight by 113 kilometers (70 statute miles) wide. The SCR was provided by the United Kingdom through a cooperative project between NASA and the British Science Research Council.

The SCMR measures differences in the thermal emission characteristics of the earth's surface. By measuring these differences in thermal emission of igneous rock, for example, it will be possible to identify their types such as dunite, basalt, syenite or granite. The SCMR will monitor infrared radiation from the earth in three spectral bands. From measurements of these thermal emissions, scientists expect to deduce the nature of surface composition, thermal maps of earth surface, and temperature gradient maps.

The combination of all three instruments, the ITPR, SCR and NEMS, for vertical sounding of the atmosphere is a powerful new approach in meteorological research from space.

The THIR experiment is primarily a service system to provide cloud and water-vapor data to experimenters. The THIR will measure infrared radiation from the earth in two spectral bands and from these measurements provide the following during both day and night portions of the orbit:

Cloud-cover pictures;

Three-dimensional mappings of cloud cover;

Temperature mapping clouds, land, and ocean surfaces;

Cirrus cloud content and contamination; and
Relative humidity.

The mission objectives of Nimbus-E are:

- Develop advanced passive radiometric and spectrometric sensors for daily global surveillance of the earth's atmosphere to provide a data basis for long-range weather forecasting specifically to compare vertical sounding techniques leading to the Global Atmospheric Research Program.

- Develop and evaluate new active and passive sensors for sounding the earth's atmosphere and mapping surface characteristics and to extend imaging into unexplored spectral regions, with higher spatial resolution.

- Develop advanced space technology and ground techniques for meteorological and other earth-observational spacecraft.

- Participate in global observation programs (World Weather Watch) by expanding daily global weather observation capability.

- Provide a supplemental source of operational meteorological data.

Sensor data obtained will be used to support the development of improved numerical methods for weather forecasting and determining atmospheric behavior. The data is expected to significantly advance the international weather information exchange of the World Meteorological Organization and the Global Atmospheric Research Program. Techniques to communicate these data rapidly and reliably will be developed concurrently.

The Nimbus satellite program was initiated by NASA in 1959 to develop an observatory system capable of meeting the research and development needs of the nation's atmospheric and earth sciences program.

The first vehicle was launched in 1964. In the intervening years the project has matured to become the nation's principal satellite program for remote-sensing research. Each observatory has grown significantly in sophistication, complexity, weight, capability and in performance.

Nimbus-E is the sixth spacecraft in a series of seven approved in the program. All of the satellites, with the exception of Nimbus-B, have met or exceeded their mission objectives. Nimbus-B never achieved orbit because of a launch vehicle failure. Nimbus-F, is scheduled for launching in 1974.

The Nimbus program is managed by NASA's Office of Applications, Washington, DC. NASA's Goddard Space Flight Center, Greenbelt, Md., is responsible for both the spacecraft and the launch vehicle.

Launch operations will be conducted for NASA by the U.S. Air Force 6595th Aerospace Test Wing under the technical supervision of NASA's Unmanned Launch Operations, Kennedy Space Center, Western Test Range Operations Division.

General Electric Co., Space Systems Organization, Valley Forge, Pa., is the Nimbus prime contractor.

McDonnell Douglas Astronautics Company, Huntington Beach, Calif., is prime contractor for the Delta launch vehicle.

More than 50 major subsystem contractors are responsible for various components in the spacecraft, launch vehicle, or ground receiving equipment. In addition, there are more than 1,000 subcontractors and vendors working on the program.

(END OF GENERAL RELEASE: BACKGROUND INFORMATION FOLLOWS)

NIMBUS-E FACTS

Launch Information:	
Vehicle	Two stage, Delta
Pad	Western Test Range, Calif., SLC-2 West
Azimuth	194 degrees True
Date	No earlier than December 12, 1972
Window	Opens shortly before 2:45 to 3:15 a.m. EST, December 12 and closes about 30 minutes later
Orbital Elements:	
Orbit	Circular, 1,110 km (690 statute miles)
Period	107 minutes
Inclination	Nearly polar, sun-synchronous, 80 degrees retrograde to the Equator
Spacecraft:	Butterfly-shaped, 3 m (10 ft.) tall, 3 m (11 ft.) wide, with a 2 m (5 ft.) diameter sensory ring for housing experiments and electronics weighing 717 kilograms (1,580 pounds)
Spacecraft lifetime:	One year
Stabilization:	Earth-oriented and three axes stabilized to within one degree
Experiments:	
Electrically Scanning Microwave (ESMR)	Thermal image of the earth and oceans unobscured by clouds

Surface Composition Mapping Radiometer (SCMR)	Identification of surface minerals
Infrared Temperature Profile Radiometer (ITPR)	Vertical temperature profile of atmosphere (CO_2)
Nimbus-E Microwave Spectrometer (NEMS)	Vertical temperature profile using O_2; water and water vapor
Selective Chopper Radiometer (SCR)	Vertical temperature profile and distribution of atmospheric gases
Temperature Humidity Infrared (THIR)	Cloud cover and water vapor mapping
Tracking:	
Orbit	22 stations of NASA's world-wide Spaceflight Tracking and Data Network
Data Acquisition Facilities	Rosman, North Carolina; Fairbanks, Alaska; Goldstone, California; Madrid, Spain; and Honeysuckle, Australia
Spacecraft Management:	Goddard Space Flight Center, Greenbelt, Md., for NASA's Office of Applications, Washington, DC
Launch Vehicle Mangement:	Goddard Space Flight Center for NASA's Office of Space Science, Washington, DC
Launch Operations:	U.S. Air Force 6595th Aerospace Test Wing, Western Test Range, Lompoc, Calif., supervision of NASA's Kennedy Space Center Unmanned Launch Operations
Prime Spacecraft Contractor:	General Electric Company Space Division Valley Forge, PA
Prime Launch Vehicle Contractor:	McDonnell Douglas Astronautics Co. Huntington Beach, Calif.

THE NIMBUS SPACECRAFT

The structural assembly consists of four major configurational elements: the attitude control segment, solar array paddles, a truss structure providing tripod connection, and a sensory ring or torus structure composed of 18 rectangular module bays plus 3 internal bays. The spacecraft accommodates up to 222 kilograms (489 pounds) of payload with a packaging volume of 1.05 cubic meters (37 cubic feet) interfacing with the sensory ring. A total earth-viewing area of 1.4 square meters (15 square feet) is available to mount sensors and antennas with a requirement to view the earth. The configurational elements supported by the spacecraft structure can be summarized as follows:

The Attitude Control Subsystem (ACS) is the upper structure that provides unobstructed, exposed mounting for the solar-paddle sun sensors, horizon scanners, and gas nozzles. The electronics mechanical drives and pneumatics are mounted in a housing for protection against space environment;

The solar array paddles attach to the shaft projecting from the Attitude Control Subsystem housing. In the launch configuration, the solar array is folded along its longitudinal axes to fit within the sensory ring envelope and is secured to the truss structure by a latch mechanism. The spacecraft is mounted on an adapter structure which is bolted to the launch vehicle extruder ring;

A truss structure provides a tripod connection between the ACS and sensory ring and allows the alignment required between the ACS and the sensors. The truss also supports the auxiliary load panel; and

The sensory ring is a doughnut-shaped structure composed of 18 rectangular module bays, 33 centimeters (13 inches) in depth. The bays house the electronic equipment and battery modules. The lower surface of the torus provides mounting space for payload and antennas. A box beam structure, mounted within the center of the torus, provides support for the larger sensor experiments and tape recorders.

NIMBUS-E EXPERIMENTS

Six highly advanced meteorological and earth resources experiments are aboard the Nimbus-E spacecraft. They are:

Electrically Scanning Microwave Radiometer (ESMR)

Infrared Temperature Profile Radiometer (ITPR)

Nimbus-E Microwave Spectrometer (NEMS)

Surface Composition Mapping Radiometer (SCMR)

Selective Chopper Radiometer (SCR)

Temperature Humidity Infrared Radiometer (THIR)

Electrically Scanning Microwave Radiometer (ESMR)

This experiment will globally map the thermal radiation emitted from the earth's surface and atmosphere at a wavelength of approximately 1.55 centimeters ($19.35GH_Z$). The emissivity of most terrestrial objects in the IR region is close to unity. However, in the microwave region, the emissivity of these objects varies greatly depending on the nature of the emitting surface. This property can be used advantageously either by itself or in conjunction with an IR scanner. As an example, thin clouds such as cirrus and stratus are relatively transparent in the microwave region and in the polar regions, where these clouds predominate, it will be possible to map surface objects such as the ice and water, since their emissivity varies greatly. It may also be possible to differentiate between the old and more recently formed ice.

Clouds with high water content will be easily identified with this microwave instrument. Thus, areas of precipitation, intense frontal and convective activity, severe storms, and other similar meteorological features can be mapped and the data used to annotate the more conventional IR or visible cloud cover maps. Over land, the amount of vegetation covering the ground or the water content in the soil can be measured.

Investigator: Dr. Thomas Wilheit
Goddard Space Flight Center

Project Engineer: Dean Smith
Goddard Space Flight Center

Co-Contractor: Space General
Division of Aerojet General
Azusa, California

GE Experiment Subsystem Engineer: William Franklin

Objective: Cloud type differentiation, precipitation intensity of frontal and convective action, severity of storms, morphology of ice cover over water, amounts of vegetation, water content of the soil.

Type of Instrument: Microwave Scanning/Imaging Radiometer

Spatial Resolution: 16 n. mi.
29 km (18 statute miles)

Orbital Average Power: 42 watts

Weight: Deployed portion 30 kilograms (67 pounds)

Location: Deployed outboard of the sensor ring in direction of flight

Size: Electronics and Antenna 1 M L x 1 M W x 1/2 M H
(3 ft. L x 3 ft. W x 1/2 ft. H)

Surface Composition Mapping Radiometer (SCMR)

The SCMR is designed to determine the nature of the earth surface composition by precise measurement of the residual radiation (reststrahlen). Extremely high sensitivity is achieved by the use of a (HgCd Te) Mercury-Cadmiun-Teluride detector cooled to 115°K by radiation to space. It is a high-resolution scanning IR imaging radiometer giving resolution size of .66 km (.4 statute miles). It has three spectral channels at 0.8 to 1.1, 8.3 to 9.3 and 10.2 to 11.2 micrometers in the atmospheric window.

The 1 micrometer channel is designed to measure reflected solar radiation from the earth (and clouds). The band was selected because it is a spectral region where the reflectivity of chlorophyl is high, thus increasing the differentiation between vegetation (normally of low reflectivity in the visible) and unvegetated areas. As such it will enhance the geological mission, as well as provide data to other earth sciences.

Thermal emission of surface objects is a function of both the temperature of the object and its emissivity, which can be a function of wavelength. In the case of quartz for example, there is a dramatic decrease in emissivity around 9 micrometers. The effect can be used to identify the nature of various surface compositions. A measurement of the radiance of highly acidic rock formation (one with a large amount of quartz) will differ from a normal rock even though the physical temperature is the same. The magnitude of the difference in apparent (or brightness) temperature can be as much as 12 to 15°C. The 3CMR on board data handling system provides both stored (tape recorded) and real-time data read-out.

Investigators: W. A. Hovis, Jr.
Goddard Space Flight Center

W. R. Callahan, Fairfield University

R. J. P. Lyon, Stanford University

Project Engineer: H. Shaw, Goddard Space Flight Center

Co-Contractor: ITT, Ft. Wayne, Indiana

GE Experiment Subsystem Engineer: Nicholas A. Koepp-Baker

Objective: To determine the nature and type of rock and sand surface composition by measuring the reststrahlen of quartz within the surface material.

Type of Instrument: IR Scanning/Imaging Radiometer

Spatial Resolution: .66 km (.41 statute miles)

Data Handling: Recorded on special recorder and transmitted via S-band Transmitter

Orbital Average Power: 15.7 watts (Duty cycle 10 minutes per orbit)

Cooling Requirements: 100^{o}K

Type of Cooler: 2 Stage Space Radiator

Weight: Sensor - 23 kilograms (50 lbs.)
Data System - 9 kilograms (19 lbs.)

Location: Under Sensor Ring

Size: Radiometer - .6 M L x .3 M W x .5 M H
(21" L x 9" W x 17" H)

Special Requirements: Special data handling system

Infrared Temperature Profile Radiometer (ITPR)

The ITPR is a seven channel scanning vertical temperature profile measuring instrument. It consists of six cassegrain telescopes facing a scanning mirror which are focused onto seven pyroelectric detectors (one telescope has a dichroic mirror which splits the beam and focuses the energy from different spectral regions onto two detectors). The spectral filters in front of the detectors select the required wavelengths. These various spectral channels are used to determine the temperature of the surface, the vertical temperature profile, and to measure water vapor radiance.

The purpose of the experiment is to test an infrared radiometer which is designed to meet the engineering and scientific demands of an operational remote temperature sounder to provide the three dimensional temperature structure of the atmosphere for operational forecasts by the mid-1970's.

The major obstacle to be overcome before satellite observations will provide atmospheric temperature and moisture profiles on a global scale is interpreting observations when thin overcast and/or broken cloud conditions exist within the field of view of the radiometer.

Investigators: W. L. Smith, National Oceanic and Atmospheric Administration

D. W. Wark, National Oceanic and Atmospheric Administration

Project Engineer: James Fischer, National Oceanic and Atmospheric Administration

Co-Contractor: Gulton Industries
Albuquerque, New Mexico (System)

Beckman Instruments
Fullerton, California (Optics)

GE Experiments Subsystem Engineer: Dario E. Galoppo

Objective: To measure radiance in 15 micron Carbon Dioxide Band, water vapor band, and window region for vertical temperature profile measurements.

Type of Instrument: Multichannel Scanning/Imaging Radiometer

Spatial Resolution: 19 n. mi.

Peak Power:

Electronics	-	10 watts
Radiometer	-	12 watts
Total	-	22 watts

Weight:

Electronics Module	7 kilograms	(16 lbs.)
Optical Head	12 kilograms	(27 lbs.)
Total	19 kilograms	(43 lbs.)

Location: Under the sensory ring

Size: Optics 20" L x 15" H x 12.2" W

Nimbus-E Microwave Spectrometer (NEMS)

The instrument has a total of five microwave radiometer channels. It will measure thermal radiation at five wavelengths near the 5-mm oxygen resonances and the 1.35-cm water vapor resonance. Each frequency is affected to a different degree by the terrestrial surface, clouds, precipitation, water vapor, and temperature profile, and therefore by appropriately interpreting a set of simultaneous equations most of these meteorological parameters can be separately estimated.

The three channels near 5-mm wavelength probe primarily the temperature profile, and two channels near 1-cm wavelength over oceans are sensitive to water vapor and liquid water, and over land can indicate surface temperature.

Infrared sensors readily probe cloud-free regions of the atmosphere, but large sections of the globe are sometimes blanketed by clouds. Microwave sensors have most of the advantages of infrared sensors, but are much less sensitive to clouds. Thus, they have the potential of providing temperature profile information, water vapor abundance, and cloud water content on a global scale under most meteorological conditions.

Investigators: Dr. D. Staelin, MIT
Mr. Frank Barath, JPL

Project Engineer: Morton Friedman
Goddard Space Flight Center

Co-Contractor: JPL, Pasadena, California

GE Experiments Subsystem Engineer: William Franklin

Objective: To measure the vertical temperature profile using the oxygen line at 5 nm., and the liquid water and water vapor radiance in the troposphere.

Type of Instrument: Multichannel Microwave Radiometer

Spatial Resolution: 185 kilometers (115 statute miles)

Average Power: 33.5 watts

Weight: 32 kilograms (70 pounds)

Location: In the Sensor Ring

Selective Chopper Radiometer (SCR)

The SCR is a 16 channel vertical temperature profile instrument. This instrument has four main sets of channels, A, B, C and D. The experiment utilizes interference filters and selected chopping, and filters acting as dichroic beam splitters and four channels utilizing carbon dioxide absorption cells. Channel A and B comprise conventional filter radiometer for measuring temperature profiles to approximately 18 kilometers (11 s.m.).

Channel C contains water vapor and window channels necessary to correct the vertical temperature profile inversion computations. It also contains two channels at 49.5 and 133.3 microns in which the indices of refraction of ice crystals are different, resulting in a measurement of the presence of cirrus clouds.

Channel D contains four wavelengths in the 2 to 4 micron region; one at the wings of the 2 micron water vapor/CO_2 absorption band, two in the 2.6 micron absorption band, and one at 3.5 micron window. These channels have different functions day and night. During the day the 3.5 micron channel measures the reflected radiation from clouds without gaseous absorption while the other three channels measure the absolute radiation temperature of the earth and its cloud cover.

Investigators: Dr. S. D. Smith
Heriot Watts University

Dr. J. T. Houghton
Oxford University

Project Engineer: Janis Bebris

Co-Contractor: Rutherford Laboratory, Chilton, Didcot, Berkshire, England
Marconi Space and Defense Systems, Frimley, Camberly, Surrey, England

GE Experiment Subsystem Engineer: David Jones

Objective: Observe global temperature structure of the atmosphere at altitudes up to 50 Km over an extended period in time; make supporting observations of water vapor distribution; and determine the density of ice particles in cirrus clouds.

Type of Instrument: Multichannel Radiometer

Spatial Resolution: 29 Km (18 statute miles)

Orbital Average Power:

Electronics	-	7.3 watts
Radiometer	-	8.7 watts
Total	-	16.0 watts

Weight:

Radiometer	-	13 kilograms	(28 pounds)
Electronics	-	5 kilograms	(10 pounds)
Total	-	18 kilograms	

Location: Under sensory ring

Size: .5 M L x .2 M W x .3 M H
(17" L x 8" W x 12" H) - Radiometer

.2 M L x .2 M W x .2 M H
(6" L x 8" W x 6 1/2" H) - Electronics

Temperature Humidity Infrared Radiometer (THIR)

The THIR which functions as the payload support cloud cover mapper is used both independently and in conjunction with other experiments. It provides data on cloud cover, ground temperatures, and water vapor distribution. It identifies cloud free areas as well as providing cloud top temperatures.

The THIR operates in two spectral intervals, one of which is an atmospheric window (10.5 - 12.5 microns) and the second is an absorption Band (6.5 - 7.0 microns). This latter band is centered near the strong water vapor absorption band. Since both these channels are in the long wave IR region, the data obtained is independent of reflected sunlight and, hence, can be used day or night. The window channel will give both two and three dimensional maps of atmospheric cloud cover. The latter can be created by measurements of vertical temperature profiles, so that the measured cloud radiances can be associated with specific altitudes. Cloud free areas present an opportunity to make thermal maps and measure gradients of oceans and land areas. The water vapor channel (since it is an absorption band) will receive energy not from the ground, but only from a band of altitudes (which can be described by its weighting function). This allows measurements of water vapor distribution, as well as cirrus cloud modification of the upwelling radiation.

Investigator: A. W. McCulloch
Goddard Space Flight Center

Project Engineer: Morton Friedman
Goddard Space Flight Center

Subcontractor: Santa Barbara Research Center
E. Trantow, Project Manager

GE Experiment Subsystem Engineer: Dario A. Galoppo

Objective: High resolution terrestial cloud and atmospheric water vapor radiation imaging

Type of Instrument: IR Scanning/Imaging Radiometer

Spatial Resolution: 10 Km (6 statute miles) in window channel; 24 Km (15 statute miles)

Peak Power: 8.0 watts

Weight:	Electronics	- 3 kilograms	(6 pounds)
	Radiometer	- 6 kilograms	(14 pounds)
	Total	- 9 kilograms	(20 pounds)

Location: Below sensory ring

Size: Radiometer - .2 M x .2 M x .4 M
7" x 7" x 15.6"

THE NIMBUS PROGRAM

Nimbus was originally conceived as a meteorological satellite concerned primarily with providing atmospheric data for improved weather forecasting. With the addition of more sophisticated sensing devices on each succeeding spacecraft, this applications/research observatory program has grown significantly in capability and performance until it now encompasses a wide range of earth sciences.

Data produced by the sensing instruments on Nimbus 1 through Nimbus 4 are now being studied and applied in the following fields:

- Oceanography (geography of the oceans and related phenomena);
- Hydrology (study of water, especially on surface of the land, in the soil and underlying rocks, and in the atmosphere);
- Geology (the science that treats the history of the earth and its life, especially as recorded in the rocks);
- Geomorphology (study of the form of the earth, the general configuration of its surface, distribution of land and water, the evolution of land forms);
- Geography (description of land, sea and air, and distribution of life, including man and his industries); and,
- Cartography (art or business of drawing or making charts or maps).

Nimbus-E will add another field to the list, agriculture, because the Electrical Scanning Microwave Radiometer (ESMR) will provide data on moisture and vegetation patterns over various land surfaces.

Nimbus-1

The first satellite in the series was launched into orbit aboard a Thor/Agena B from the Western Test Range in the early morning of August 28, 1964. In spite of a short Agena second burn, resulting in an eccentric orbit with a 932 km (579 s.m.) apogee and 422 km (262 s.m.) perigee instead of the 1,110 km (690 s.m.) circular orbit, Nimbus-1 became fully operational shortly after orbit insertion.

Nimbus-1 worked for about one month before it stopped operating due to a failure of the solar array drive system which is a major part of the satellite's power system. During its lifetime, it proved that a weather satellite could maintain three-axis stability and earth orientation. It provided man with the first high resolution television and infrared weather photos from a satellite.

Nimbus-1 carried three experiments -- the Automatic Picture Transmission (APT) camera, The Advanced Vidicon Camera Subsystem (AVCS) and the High Resolution Infrared Radiometer (HRIR). The APT camera system was warmly welcomed by meteorologists world-wide because for the first time weather pictures could be received at small, inexpensive, portable stations as the satellite passed overhead.

The first Nimbus spacecraft took Hurricane Cleo's portrait during its first day in orbit and subsequently tracked many other hurricanes and Pacific typhoons. In addition, the pictures enabled cartographers to correct inaccuracies on relief maps and supplied better definition of the formation of the Antarctic ice front.

Nimbus-2

Nimbus-2 was launched into a near perfect orbit by a TAT/Agena B on May 15, 1966. It carried the same instruments as Nimbus-1, plus a Medium Resolution Infrared Radiometer (MRIR). The spacecraft design life was 6 months (about 2,500 orbits). The mission was finally terminated in Orbit 13,029 on January 17, 1969, after almost 33 months of operation.

By the time Nimbus 2 was launched, the number of APT stations had grown from 65 to over 300. situated in some 43 countries. The system was modified so that HRIR (infrared) pictures could also be received by the APT stations. Analysis methods and computer programs were improved, eliminating the need for cloud-free data.

Temperature patterns could be obtained of lakes and ocean currents (of vital interest to shipping and fishing industries) and thermal pollution could also be identified.

The MRIR experiment aboard Nimbus-2 measured electromagnetic radiation emitted and reflected from the earth in five wavelength intervals from visible to infrared (invisible to the human eye). The data permitted detailed study of the effect of water vapor, carbon dioxide, and ozone on the earth's heat balance.

Nimbus-3

Nimbus-3 was successfully launched April 14, 1969. The spacecraft carried seven meteorological experiments, plus a two-unit nuclear isotopic system for generating electrical power, the SNAP-19 (Systems for Nuclear Auxiliary Power), developed by the Atomic Energy Commission.

The Nimbus-3 meteorological experiments were:

- Infrared Interferometer Spectrometer (IRIS)
- Satellite Infrared Spectrometer (SIRS)
- Interrogation Recording and Location System (IRLS)
- High Resolution Infrared Radiometer (HRIR)
- Medium Resolution Infrared Radiometer (MRIR)
- Monitor of Ultraviolet Solar Energy (MUSE)
- Image Disector Camera System (IDCS)

The vertical temperature measurements of the atmosphere made by Nimbus-3 were acclaimed by weathermen as one of the most significant events in the history of meteorology. The instrument which made this possible was the SIRS (SIRS was developed by the Environmental Science Service Administration).

The SIRS measured, simultaneously, infrared spectral radiances in narrow intervals of the carbon dioxide absorption band, from which temperature profiles of the earth's atmosphere can be developed.

The first temperature profile was constructed from SIRS data on April 14, 1969, and provided excellent correlation with radiosonde measurements (weather balloons) from Kingston, Jamaica. Subsequent correlation with data taken over the United States and the Pacific Ocean was also excellent.

Prior to Nimbus-3, data over the oceans had been scanty, so that only 20 percent of the world had detailed weather information. SIRS data made it possible to obtain temperature data over the entire earth with an accuracy of 2 degrees F above 7,000 meters (20,000 feet) and 4 degrees below 7,000 meters (20,000 feet).

The quality of the SIRS data is attributed to the design features of the instrument and to the very stable environment of Nimbus-3.

The IRIS experiment aboard Nimbus-3 provided World-wide atmospheric information, including ozone distribution, on a scale not previously possible. Ozone measurements can be immensely valuable for weather prediction in the vast tropical region and southern hemisphere where conventional meteorological network-gathered upper air data is sparse. Temperature, humidity, and ozone profiles were developed which correlated excellently with radiosonde and ground-based spectrometer data.

Nimbus-4

Nimbus-4 was launched April 8, 1970. Six of the nine experiments are still capable of providing data. The experiments are:

- Infrared Interferometer Spectrometer (IRIS)
- Satellite Infrared Spectrometer (SIRS) - operable
- Interrogation Recording & Location System (IRLS) - operable

- Monitor of Ultraviolet Solar Energy (MUSE) - operable

- Image Dissector Camera System (IDCS) - operable

- Backscatter Ultraviolet Spectrometer (BUV) - operable

- Filter Wedge Spectrometer (FWS)

- Selective Chopper Radiometer (SCR) - operable

- Temperature Humidity Infrared Radiometer (THIR)

Three new experiments (BUV, FWS and SCR) were carried by Nimbus-4 as well as three significantly improved versions of sensors (IRIS, SIRS and IRLS) which had flown on earlier Nimbus missions. In addition, there are three experiments (THIR, IDCS and MUSE) similar to those aboard Nimbus-3.

THE DELTA LAUNCH VEHICLE

The general characteristics of the Delta for the Nimbus-E mission are:

Total Height:	33 m (105 ft.)
Total Weight:	About 113,400 kg (250,000 lbs.)
Maximum Body Diameter: (Not including solids)	2.44 m (8 ft.)

The Delta first stage is a modified Thor booster incorporating nine strap-on solid fuel rocket motors. The booster is powered by an engine using liquid oxygen and RJ-1 Kerosene. The main engine is gimbal mounted to provide pitch and yaw control from lift-off to main engine cut-off (MECO). Two liquid propellant vernier engines provide roll control throughout the first stage operation, and pitch and yaw control from MECO to first stage separation.

The second stage is powered by a liquid-fuel pressure-fed engine which is also gimbal mounted to provide pitch and yaw control through second stage burn out. The second stage propellants are Nitrogen Tetroxide (N_2O_4) for the oxidizer and Aerozine 50 for the fuel. A nitrogen gas system using eight fixed nozzles provides roll control during powered and coast flight as well as pitch and yaw control after second stage cutoff.

The all inertial guidance system, consisting of an Inertial Measurement Unit (adapted from the Apollo Lunar Module) and digital guidance computer (adapted from the Centaur launch vehicle program), control the vehicle and sequence of operations from lift-off to spacecraft separation. The sensor package provides vehicle attitude and acceleration information to the guidance computer. The guidance computer generates vehicle steering commands to each stage to correct trajectory deviations by comparing computed position and velocity against prestored values. This system will permit more accurate orbits and will be more flexible than the radio command guidance system used by the earlier Delta rocket.

The Delta program is managed for NASA's Office of Space Science by the Goddard Space Flight Center. Launch services are provided by the U.S. Air Force 6595th Aerospace Test Wing under supervision of NASA's Kennedy Space Center, Unmanned Launch Operations. The Delta prime contractor is McDonnell Douglas Astronautics Company, Huntington Beach, California.

The Flight

The Thor main engine and six of the solid motors are ignited at lift-off, and the remaining three solids are ignited later at altitude. Between T plus 100 and 105 seconds the vehicle is yawed approximately one degree to achieve the desired inclination of the transfer orbit.

The Nimbus-E flight plans calls for the second stage to undergo two burns. The first burn will place the vehicle into an elliptical transfer orbit with a perigee (closest point to Earth) of 185 km (115 statute miles) and an apogee (farthest point from Earth) of about 1,110 km (690 statute miles).

The orbiting second stage will be restarted (about 57 minutes after lift-off) over the Indian Ocean near Tananarive to circularize the Nimbus-E orbit. This second burn will last for 12 seconds and place the spacecraft into a final circular orbit at an altitude of 1,110 km (690 statute miles).

About 3 1/2 minutes after the second stage shuts down for the second time, the Nimbus-E separation sequence will begin. Gas jets aboard Delta will turn it, and Nimbus, to an attitude of 80 degrees of the local verticle of the Earth. A spring system will then separate Nimbus-E from the Delta. The Nimbus-E attitude and control subsystem will then be activated so the spacecraft becomes Earth oriented and stabilized in all three axes.

At about 15 minutes after spacecraft separation (and again 15 minutes later at T plus 77 minutes and T plus 93 minutes respectively) the Delta second stage will be ignited for the third and fourth times in a special test related to the restart capability of the new second stage. The fourth and final burn will place the Delta second stage into a perigee of 1,085 km (674 statute miles) and an apogee of 1,360 km (845 statute miles).

MAJOR DELTA 93/NIMBUS-E FLIGHT EVENTS

Event	Time	Altitude	Velocity (Kilometers Per Hour)
First Solid Motors Burn-out (six solids)	T plus 39 sec.	6 km (4 s.m.)	1530 km/HR (951 mph)
Three Solid Motors Ignite	T plus 39 sec.	6 km (4 s.m.)	1530 km/HR (951 mph)
Second Solid Motor Burnout (three solids)	T plus 1 min. 18 sec.	21 km (13 s.m.)	3285 km/HR (2041 mph)
Solid Motor Separation (all nine solids)	T plus 1 min. 25 sec.	27 km (16 s.m.)	3495 km/HR (2172 mph)
Main Engine Cut Off (MECO)	T plus 3 min. 40 sec.	99 km (61 s.m.)	17,515 km/HR (10,883 mph)
Vernier Engine Cut Off (VECO)	T plus 3 min. 46 sec.	104 km (65 s.m.)	17,525 km/HR (10,890 mph)
Stage 1, Stage II Separation	T plus 3 min. 48 sec.	106 km (66 s.m.)	17,515 km/HR (10,883 mph)
Stage II Ignition	T plus 3 min. 52 sec.	109 km (68 s.m.)	17,490 km/HR (10,868 mph)
Jettison Fairing	T plus 4 min. 25 sec.	130 km (81 s.m.)	18,090 km/HR (11,241 mph)
1st Second Engine Cut Off (SECO)	T plus 9 min. 4 sec.	185 km (115 s.m.)	29,305 km/HR (18,208 mph)
Restart Second Stage	T plus 57 min. 5 sec.	1110 km (690 s.m.)	25,810 km/HR (16,037 mph)
Second SECO	T plus 57 min. 17 sec.	1110 km (690 s.m.)	26,680 km/HR (16,579 mph)
Spacecraft Separation	T plus 60 min. 38 sec.	1110 km (690 s.m.)	26,680 km/HR (16,579 mph)

<u>KSC-WTR</u>

NASA launch operations from the Western Test Range are conducted by Kennedy Space Center Unmanned Launch Operations Directorate. Most of the KSC contingent are on permanent assignment at Vandenberg AFB, although a small supplemental group from KSC in Florida assists during the final preparations and launch countdown.

The Nimbus space vehicle has been undergoing checkout and launch preparations since the first stage of the Delta booster arrived in mid-October. The booster was erected at launch complex SLC-2W on the 19th of October and the nine auxiliary solid motors were attached to the booster on the 25th and 26th of October.

The Delta second stage was hoisted atop the first stage on October 30. Tests were conducted of the launch vehicle electrical, mechanical, propulsion, and guidance systems before the spacecraft was mated to the launch vehicle. After spacecraft mate, a simulated flight was conducted, the last overall test of the vehicle.

NIMBUS-E PROJECT OFFICIALS

NASA Headquarters, Washington, DC

Mr. Leonard Jaffe	Deputy Associate Administrator Office of Applications (Acting) Director, Earth Observations Program
Mr. Bruton B. Schardt	Nimbus Program Manager
Mr. Joseph B. Mahon	Director, Launch Vehicles and Propulsion Program
Mr. I. T. Gillam, IV	Delta Program Manager

Goddard Space Flight Center, Greenbelt, MD

Dr. John F. Clark	Director
Mr. Robert N. Lindley	Director of Projects
Mr. Harry Press	Associate Director for Earth Observation Satellites
Mr. Stanley Weiland	Project Manager
Dr. William Nordberg	Project Scientist
Mr. William R. Schindler	Delta Project Manager
Mr. George D. Hogan	Observatory Manager
Mr. Wilber B. Huston	Mission Director
Mr. Ralph B. Shapiro	Operations Manager
Mr. John W. Lindstrom, Jr.	Manager, Nimbus Data Utilization Center
Mr. Richard Ormsby	Manager, Nimbus Technical Control Center

Mr. E. Michael Chewning	Network Support Manager
Mr. William F. Mack	Mission Support Manager

Kennedy Space Center, FL

Mr. John J. Neilon	Director, Unmanned Launch Operations
Mr. Wilmer Thacker	Manager, Delta Operations (WTR)
Mr. Eugene Langenfeld	Spacecraft Coordinator

General Electric Company, Valley Forge, PA

Mr. I. S. Hass	General Manager, Earth Observatory Programs
Mr. L. T. Seaman	Manager, Observatory Systems Program
Mr. Joseph Balch	Deputy Manager, Nimbus Program

McDonnell-Douglas Astronautics Company, Huntington Beach, CA

Mr. E. W. Bonnett	Delta Project Manager

NIMBUS-E EXPERIMENTERS

Dr. Thomas T. Wilheit Goddard Space Flight Center	Electrically Scanning Microwave Radiometer (ESMR)
Dr. Warren A. Hovis, Jr. Goddard Space Flight Center W. R. Callahan Fairfield University R. J. P. Lyon Stanford University	Surface Composition Mapping Radiometer (SCMR)
W. L. Smith & D. W. Wark National Oceanic and Atmospheric Administration	Infrared Temperature Profile Radiometer (ITPR)
Dr. David H. Staelin, MIT Frank Barath, JPL	Nimbus-E Microwave Spectrometer
S. D. Smith Heriot Watts University J. T. Houghton Oxford University	Selective Chopper Radiometer (SCR)
Andrew W. McCulloch Goddard Space Flight Center	Temperature Humidity Infrared Radiometer (THIR)

SPACECRAFT CONTRACTORS

Company	Subsystem
General Electric Co. Space Systems Organization Valley Forge, PA	Prime Contractor Nimbus D Integration and Test, Stabilization and Control Subsystem Integration, Spacecraft Structure and Antennas
California Computer Products Los Angeles, CA	Command Clock
Radiation, Inc. Melbourne, FL	Versatile Information Processor, (VIP), or housekeeping telemetry
Radio Corporation of America Astro Electronics Division Princeton, NJ	High Data Rate Storage System, Command Receivers, Solar Power System
Sperry Gyroscope Great Neck, NY	Rate Measuring Package

Major Ground Equipment Contractors

Company	Responsibility
Terratek, Inc., A subsidary of Allied Research Associates, Inc Seabrook, MD	Operate the Nimbus Data Utilization Center
Control Data Corp. Minneapolis, MN	Ground Station Computers
Lear Siegler, Inc. Anaheim, CA	Computer System for Decomputating Versatile Information Processor (VIP) Telemetry Data
RCA Service Co. Cherry Hill, NJ	Operate the Nimbus Data Handling System at the Goddard Space Flight Center and Alaska
Ithaco, Inc. Ithaca, NY	Attitude Control Components and Subsystems

PRIME EXPERIMENT CONTRACTORS

Space General, Division of Aerojet General Azusa, CA	Electrically Scanning Microwave Radiometer (ESMR)
ITT Ft. Wayne, IN	Surface Composition Mapping Radiometer (SCMR)
Gulton Industries (Under NOAA Contract) Albuquerque, NM	Infrared Temperature Profile Radiometer (ITPR) -- (System)
Beckman Instruments Fullerton, CA	(ITPR) -- (Optics)
JPL Pasadena, CA	Nimbus-E Microwave Spectrometer (NEMS)
Rutherford Lab, Chilton, Didcot, Berkshire, England Marconi Space and Defense Systems, Frimley, Camberly, Surrey, England	Selective Chopper Radiometer (SCR)
Santa Barbara Research Center Santa Barbara, CA	Temperature Humidity Infrared Radiometer (THIR)

MAJOR DELTA LAUNCH VEHICLE CONTRACTORS

Company	Responsibility
McDonnell Douglas Astronautics Co. Huntington Beach, CA	Prime Contractor
Aerojet General Corp. Sacramento, CA	Second Stage propulsion system
Hamilton Standard Division of United Aircraft Corp. Farmington, CT	Inertial Measuring Unit Portion of the inertial guidance system

Company	Responsibility
Rocketdyne, North American Rockwell Corporation Canoga Park, CA	First stage main engine and vernier engines
Teledyne Industries, Inc. Northridge, CA	Computer for inertial guidance system
Thiokol Chemical Corporation Elkton, MD	Solid Motors

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