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ABSTRACT

This publication describes forecasting weather activity using satellites. Information is included on the development of weather satellites, the National Oceanic and Atmospheric Administration (NOAA) Satellite System (including the polar-orbiting satellites), and the Geostationary Operational Environmental Satellite (GOES). The publication discusses the value of weather satellites; search and rescue; storm and rainfall forecasting; volcanic monitoring; fire detection; ocean temperature measurement; vegetation index mapping; and fish tracking. The instrumentation carried by weather satellites is discussed and definitions of the vocabulary used are listed. (YP)

NASA Facts

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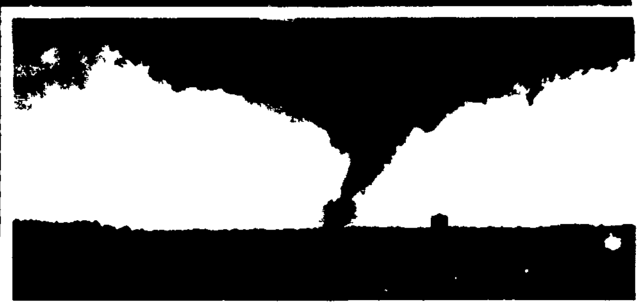

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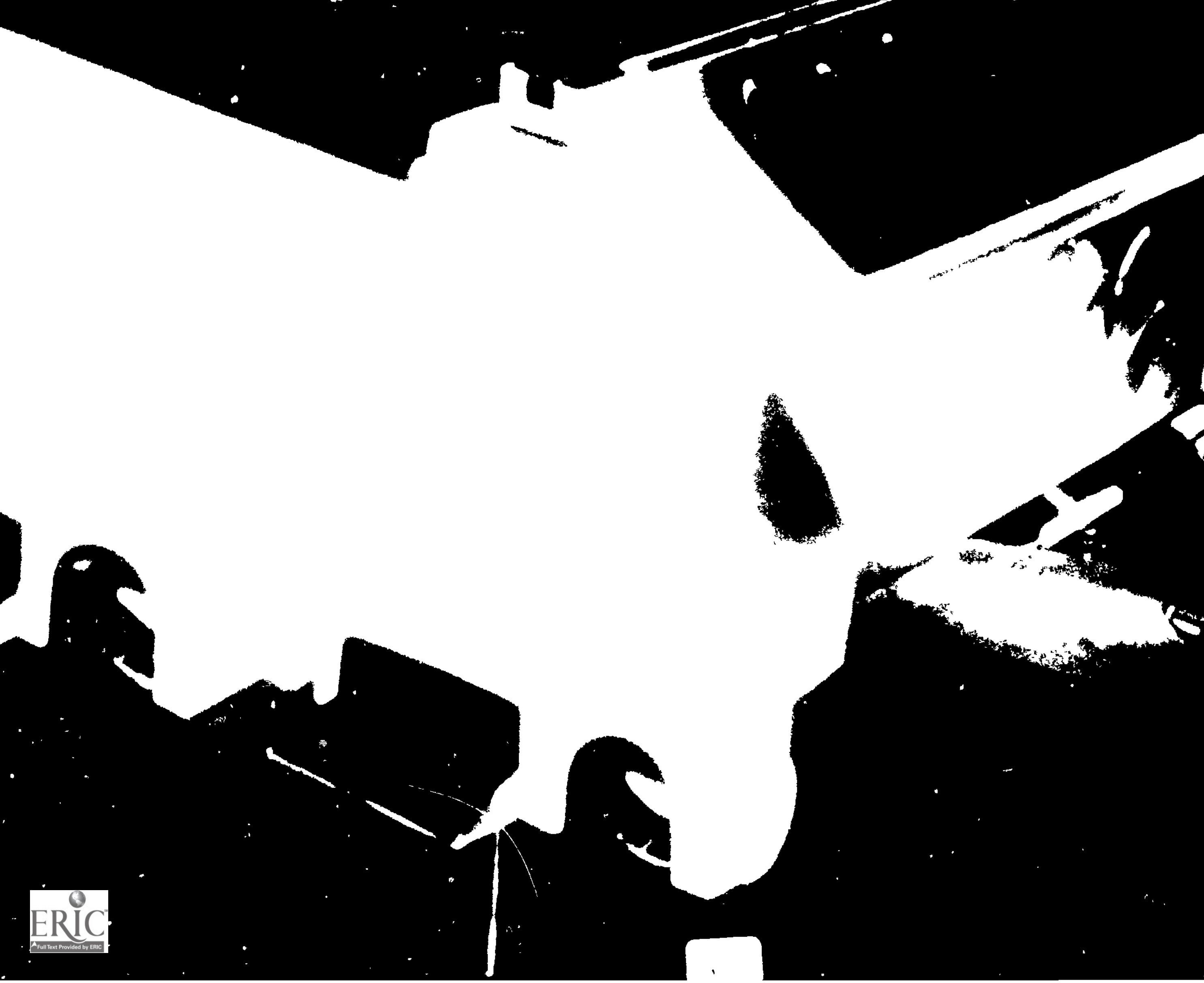


Sentinels in the Sky: Weather Satellites

By Robert Haynes

This publication was developed as a joint effort between NASA and the National Oceanic and Atmospheric Administration (NOAA). Special thanks go to Basil Littin, Public Affairs Officer, Ron Gird, Satellite Meteorologist, and James Sparkman, Physical Scientist, NOAA.

When we talk about the weather, we often find ourselves fascinated with its complexity and capriciousness. We are as curious as were our ancient ancestors, who were acutely aware of how weather affected their food supply and survival. Some tribes and cultures erected permanent structures, with which they could continually chart the course of the Sun and monitor seasonal changes.

Today we are no less relenting in our interest in the weather. We have built and launched into space a family of weather satellites that watch the weather from high above us. These "sentinels in the sky" are constantly on guard for those inevitable moments when friendly weather turns to foe.

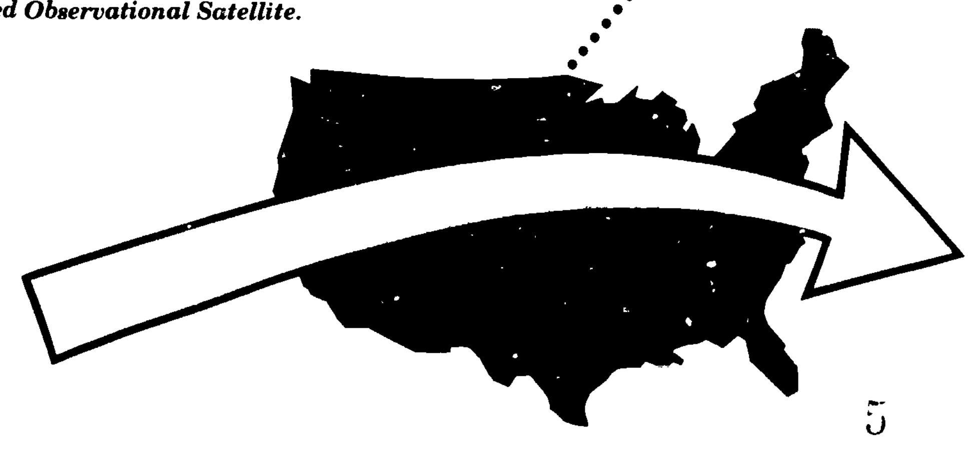
They are tireless observers, telling us when a distant low-pressure system over the Atlantic may develop into a hurricane and threaten our lives with damaging winds. They monitor the warming ocean currents of an El Niño that may affect crops in the United States or Europe by changing expected precipitation patterns. They allow us to understand the weather with some degree of certainty, and not be victims of nature's whims.

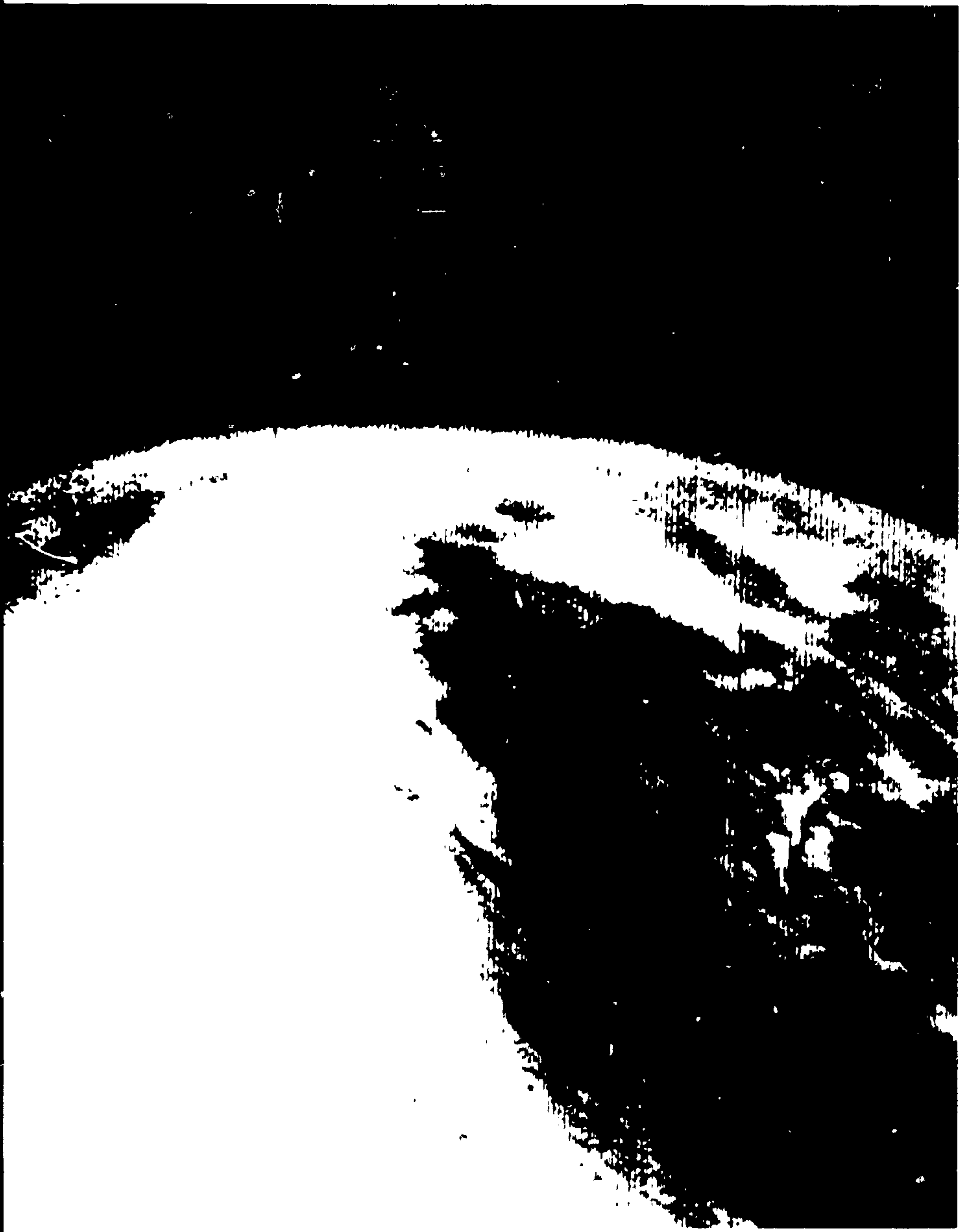
Benjamin Franklin was the first American to suggest weather could be predicted. From newspaper articles, Franklin deduced that severe storms generally move across the nation from west to east. He further deduced that if this were so, observers could follow a storm and notify those ahead of its path that it was coming.

Franklin's ideas were finally put to practical use shortly after the telegraph was invented in 1837. This revolutionary form of communication soon spanned the country. It wasn't long until it was used to link a network of weather watchers, who clicked their observations along telegraph lines to a central office where a national weather map was created.

Today, satellites are those observers, beeping messages to a receiving antenna connected to a computer. Meteorologists analyze the messages and use the data to predict how the weather will behave and how it will affect us.

TITLE PAGE: The current TIROS-N series of polar-orbiting satellites represent the fourth generation of these "Sentinels in the Sky." TIROS stands for Television Infrared Observational Satellite.





First television picture from space. On April 1, 1960, the TIROS-1 weather satellite sent this image. Since then, bigger and better satellites have multiplied our knowledge about weather and its behavior.

A View From Above

Weather watchers along the telegraph lines had to base their understanding about the weather solely on what they could see from the ground. Well into the 20th century, meteorologists still based most of their knowledge on ground observations. Having no way to observe or study weather patterns over long periods, and no way to monitor cloudtops, meteorologists had little notion of large-scale weather behavior. If aerial views were made, they were taken from airplanes or weather balloons but were of too short a duration to provide the kind of information needed. Some progress was made in 1959 when the U.S. Army Signal Corps launched *Vanguard* II, but it was also short lived.

Then, in 1960, the National Aeronautics and Space Administration (NASA) placed in orbit the first TIROS (Television Infrared Observational Satellite). With its tiny TV cameras, TIROS flew over more than two-thirds of the Earth's surface. Its pictures revealed global weather systems as marked by the patterns of clouds, and provided meteorologists with a new tool–a nephanalysis, or cloud chart. These high-altitude views sharpened meteorologists' scrutiny of weather and of the environment, and promised even greater benefits to come.

Weather watchers along the telegraph lines had to base their understanding of the weather solely on what they could see from the ground.

NASA built and launched bigger and better TIROS satellites. By 1965 nine more TIROS satellites had been launched. They had progressively longer operational times and carried infrared radiometers to study Earth's heat distribution. Several satellites were placed in polar orbits rather than near-equatorial ones so they could take pictures over more of the Earth's surface.

TIROS 8 had the first Automatic Picture Transmission (APT) equipment. This instrument allowed pictures to be sent back to Earth right after they had been taken instead of stored for later transmission. Eventually APT pictures could be received on fairly simple ground stations.

TIROS 9 and 10 were test satellites of improved configurations for the TIROS Operational Satellite (TOS) system. TOS satellites were often called ESSA after the government agency that financed and operated them, the Environmental Sciences Services Administration. ESSA
(continued on page 6)

Weather satellites are typically launched on unmanned rockets such as the Atlas and the Delta. Originally developed as weapon systems, these rockets have become the workhorses for launching civilian as well as military satellites.

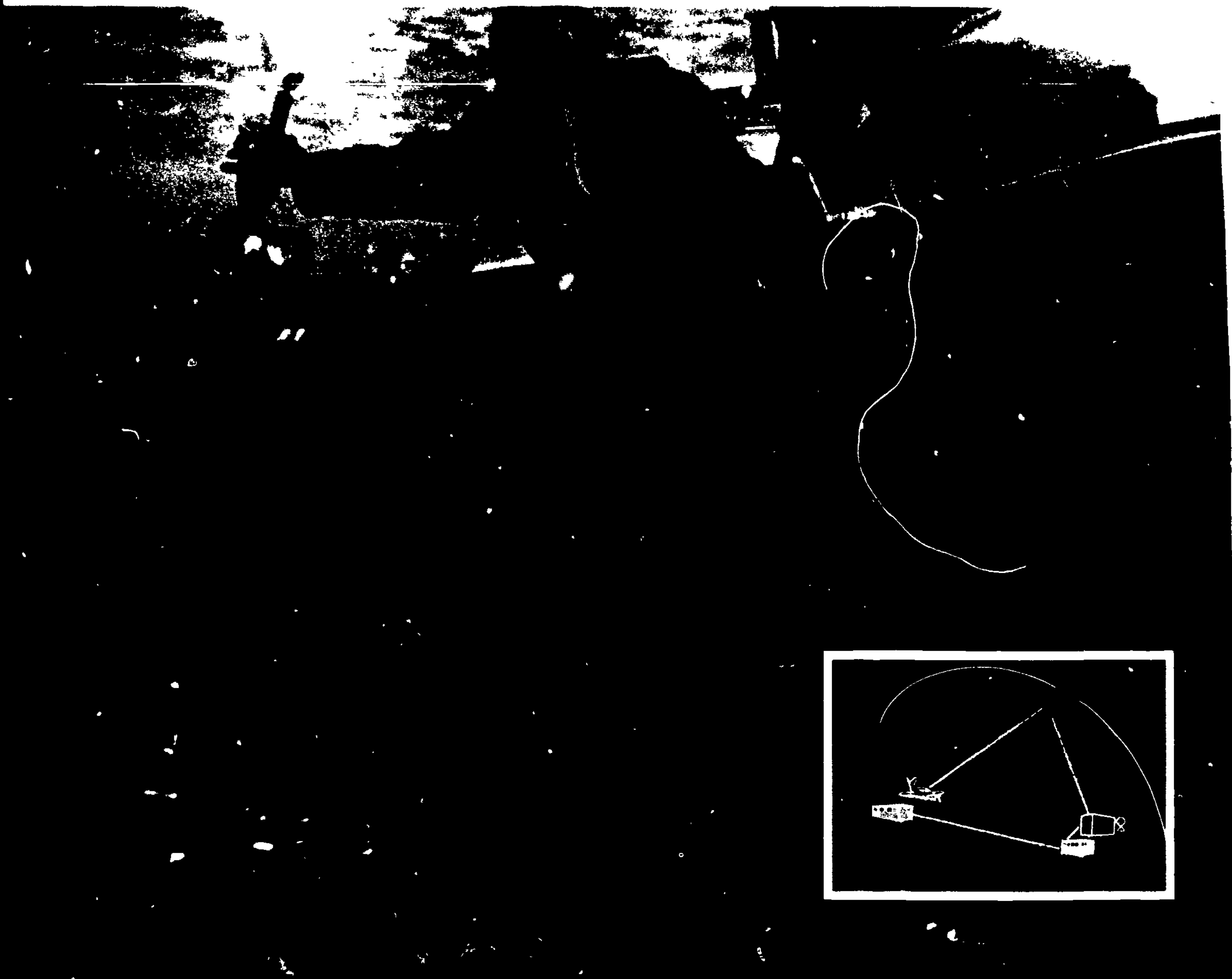
Search and Rescue

The concept for a satellite-aided search and rescue project (SARSAT) began almost as soon as the first satellites were placed in Earth orbit. Experimental equipment had been placed on the early Nimbus satellites, and the first operational system was on TIROS. In 1976, the effort became an international project, with the United States, Canada, and France participating.

In 1980, the Soviet Union agreed to equip COSMOS satellites with COSPAS repeaters. Other nations have since joined in. The COSPAS/SARSAT satellites monitor the entire surface of the Earth, listening for distress signals from downed airplanes, capsized boats, and persons in other emergencies.

These signals are transmitted to special ground receiving stations in the United States and overseas. The location of the signal is computed and the nearest rescue coordination center is notified. When an air or sea rescue team goes out, it has a "fix" within a few miles of the actual emergency. Satellite search has cut recovery time from days to a few hours.

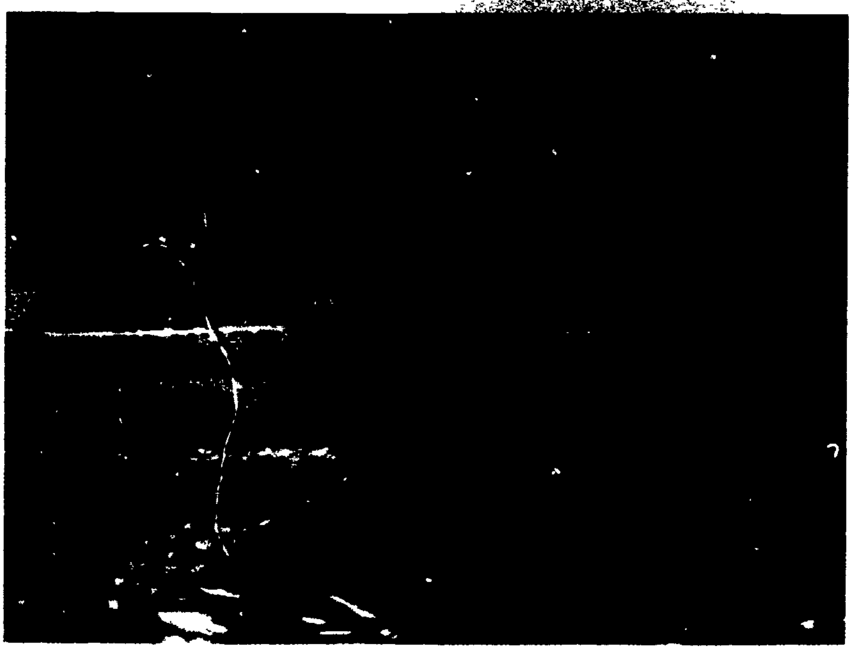
The program has been instrumental not only in saving hundreds of lives but also in saving millions of dollars in search efforts. The system is proving increasingly valuable as additional enhancements and improvements are made.



Aviators and mariners in distress transmit an emergency signal to the COSPAS/SARSAT satellite. The signal is received and retransmitted to a ground receiving station, where a U.S. Coast Guard or Civil Air Patrol rescue team is dispatched.

The ground receiving station processes the signal and pinpoints the location. The location is given to the U.S. Mission Control Center, which alerts rescue teams in the area.

"Thanks to COSPAS/SARSAT for saving us. Shortly after our rescue, the weather on the ice cap became rather poor and the winds were so high that several days might have elapsed before our rescue, had our position not been pinpointed so accurately by satellite," Dr. Justis reported. They are pictured here, ELT (emergency locater transmitter) in hand, beside their new plane – the damaged one was abandoned on the ice cap. (Rescue June 1986)



Four hours after crash-landing their twin-engined plane 9,300 feet above sea level on the Greenland ice cap, Dr. E. Jeff Justis, Memphis surgeon, and his wife, Sally, were spotted by a search plane that had been directed to their position by COSPAS/SARSAT, the satellite search and rescue system. Two hours later, a Danish helicopter picked them up.

(continued from page 4)

satellites were placed in Sun-synchronous orbits, so they would pass over the same positions on the Earth at the same time every day. This would allow meteorologists to view local cloud cover changes on a 24-hour basis.

With the success of TIROS, NASA created a second-generation research satellite called *Nimbus*. More complex than TIROS, *Nimbus* satellites carried an APT system, an advanced TV cloud-mapping camera system, and an infrared radiometer that allowed pictures at night for the first time.

Seven *Nimbus* satellites were placed in orbit between 1964 and 1978. *Nimbus* satellites tested space-borne meteorological equipment that led to a fully operational weather observing service with 24-hour-a-day coverage.

Today, weather satellites scan the Earth. With their vigilance, not a single tropical storm anywhere on Earth goes undetected. The early detection and warnings they provide have saved thousands of lives.

When Mount St. Helens erupted on May 18, 1980, weather satellites looked on as tons of volcanic ash were spewed into the atmosphere. They photographed hourly the eastwardly spread of the massive dust clouds, allowing meteorologists to warn aircraft pilots of the danger, and to study the effects such an explosion might have on the world's climate. Fortunately, those effects in this instance were slight.

Satellites are the workhorses of a complete weather monitoring system. They scan the globe day and night, transmitting back weather information such as temperatures, cloud formations, wind patterns, sea currents, etc. For years, the swirling cloud patterns that weather satellites see have been standard props for TV weathercasters. Hardly anyone can tune in a weathercast without seeing a "satellite view."

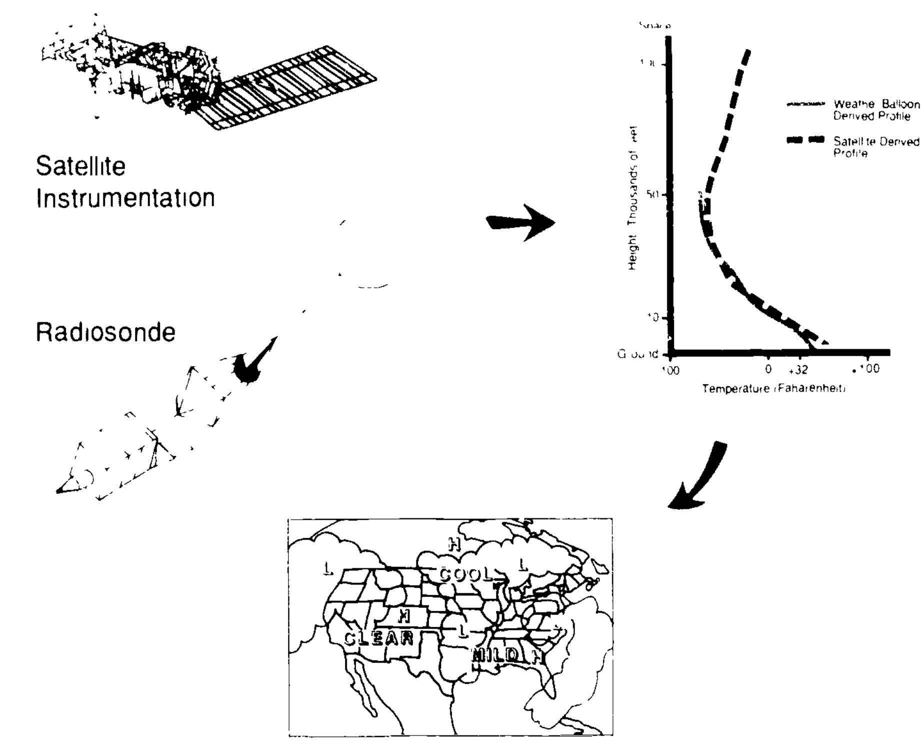
Across Government Lines

Our understanding of the weather has multiplied during the years weather satellites have operated. The services these weather watchers provide span many governmental lines both here and overseas. NASA contributes the research and development, and over sees procurement of these spacecraft, and evaluates their performance in flight. Once NASA launches the satellites into their appropriate orbits, the responsibility for operating them falls to another government agency; however, NASA continues its research role even after the spacecraft become operational. NASA's broad space program generates advanced technologies that are tested and applied to produce new generations of satellites.

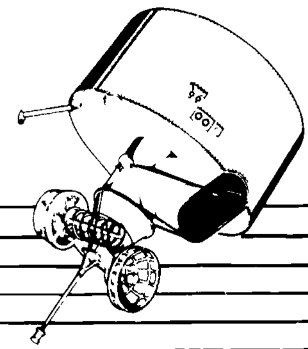
The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) is the government agency that directs the nation's system of weather satellites. NOAA manages the processing and distribution of the millions of bits of data and images these satellites produce daily. The prime consumer is NOAA's Weather Service, which employs satellite data to create forecasts for television, radio, and weather advisory services. Satellite information is also shared by government departments such as Agriculture, Interior, Defense, Transportation, and Energy.

Weather satellites create an international network. Information is routinely shared among the member nations of the World Meteorological Organization as well as with nations that operate their own weather satellites.

Weather Monitoring System



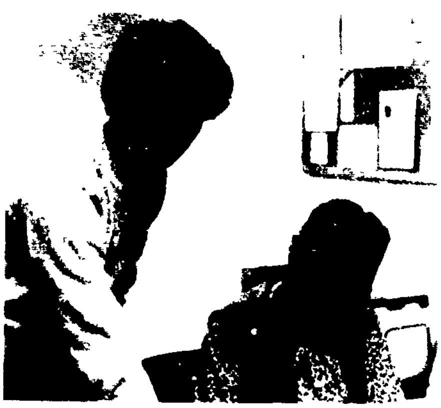
Weather Forecast



such as Japan, India, the Soviet Union, and members of the European Space Agency.

NOAA Satellite System

NOAA was established in 1970 inside the U.S. Department of Commerce with the mission to ensure the safety of the general public from atmospheric phenomena and to provide the public with an understanding of the Earth's environment and resources. NOAA was also given the responsibility to chart the airways, oceans, and waters of the United States, and to guide the development of marine fisheries. One of the ways NOAA does this is by operating its system of weather satellites. Command and Data Acquisition Stations in Wallops, Virginia, and Fairbanks, Alaska, send commands to the orbiting satellites and receive data transmissions. A fully staffed weather satellite processing and distribution facility is located in Suitland, Maryland, just outside Washington, D.C.



Besides looking down on weather conditions around the world, satellites perform a host of other services. They assess crop gr wth and other agricultural conditions, sense shifting ocean currents, and measure surface temperatures of oceans and land. They relay data from surface instruments that sense tide conditions, Earth tremors, river levels, and precipitation.

Weather satellites also broadcast the correct time as it is precisely measured by the Department of Commerce's National Bureau of Standards. They receive weather data from ocean buoys, weather balloons, and aircraft in flight, relaying this data to the Data Acquisition Stations. Using a facsimile technique, they also broadcast cloud cover pictures and charts. (See "The Value of Weather Satellites.")

The TIROS-N series of satellites broadcast pictures and data so that any properly equipped receiving station on the ground can receive the pictures without needing to link with an expensive computer. This capability has prompted many schools across the country to install antennas and to build their own weather receiving systems. (Secondary school teachers may obtain a copy of *Teacher's Guide for Building and Operating Weather Satellite Ground Stations* from the Educational Programs Officer. NASA Goddard Space Flight Center (202.3), Greenbelt, MD 20771.)

NOAA's operational weather satellite system comprises two types of satellites: Polar Orbiters and Geostationary Satellites (GOES). The polar orbiters constantly circle the globe, providing coverage of the globe every day. They circle in low orbits (850 km) and support large-scale, multiday forecasts. The GOES satellites circle in a much higher orbit (35,000 km) so that their orbital rate exactly matches the rotation of the Earth's surface. This keeps them above a fixed spot on the surface, providing a constant vigil for severe weather conditions that may spawn tornados, flash floods, hail storms, and hurricanes. Both kinds of satellites are necessary to provide a complete global weather monitoring system.

The Value of Weather Satellites

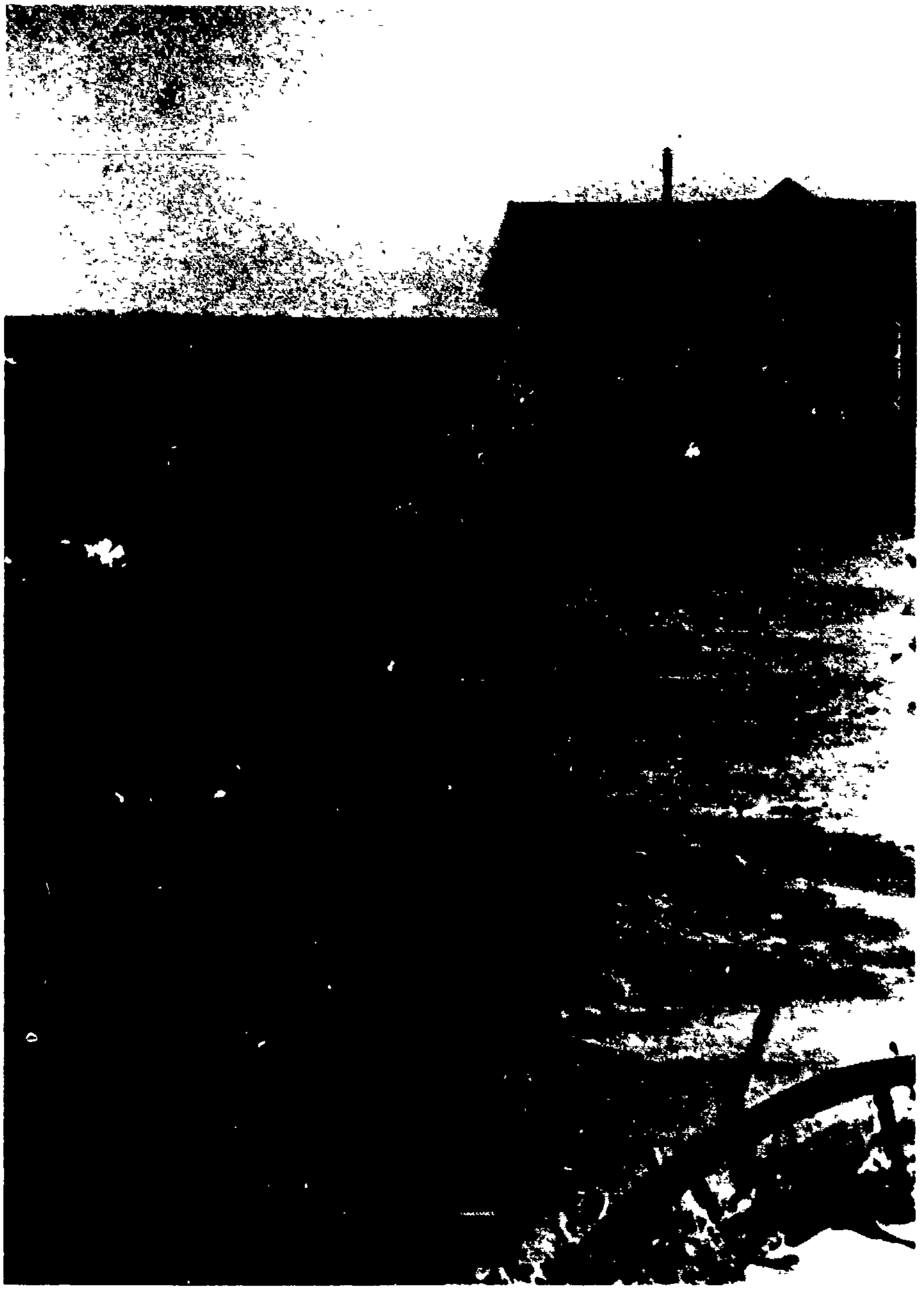
The value of weather satellites to save lives has been known from the beginning. Their ability to track storms and permit early warnings has been their greatest contribution. However, their benefits do not end with observing the tops of clouds and storm systems.

Satellites can pinpoint different temperature boundaries in ocean surface areas, and give commer-

This view of the Western Hemisphere is a typical image issued by the National Weather Service operated by NOAA. This one is unique in that it shows two hurricanes in the same frame: one in the Gulf of Mexico and another off the coast of California.

cial fishermen vital clues to the whereabouts of commercial fish such as tuna, herring, and swordfish. They can provide early frost warnings, which can save millions of dollars a day for citrus growers who must then heat their groves. In Hawaii, rain warnings are provided, giving crucial information for sugarcane harvesting. Satellites also play a role in forest management and fire control.

NOAA's polar-orbiting satellites observe snow and ice melting conditions, enabling water supply managers to plan irrigation and flood control. This is especially important to the multi-billion dollar agricultural economies of our western states, where mountain runoff provides an estimated 70 percent of the water supply. Satellite ice monitoring helps extend the shipping season on the Great Lakes into the winter months, generating extra economic activity for middle America and neighboring Canadian provinces.



The benefits of weather satellites do not end with observing clouds. By measuring the greenness of plant chlorophyl, satellites can pinpoint areas of drought, desert creep, or deforestation.

Tornadoes are among the most violent storms in nature. As yet, we still cannot predict when and where they will strike. But with the aid of weather satellites we can delineate "most likely areas" and issue advisories to people who may be affected.

Severe Storm Support

Geostationary satellites continuously watch atmospheric conditions that breed tornadoes, squall lines, and other severe storms. The "triggers" for such events often can be detected by satellites before the actual storms develop. When they do develop, the satellites monitor storm life cycles, and track movements. The value of this information is increasing steadily as new applications and small interactive computer systems are developed from the partnership of government, industry, and our high schools and universities.

Rainfall

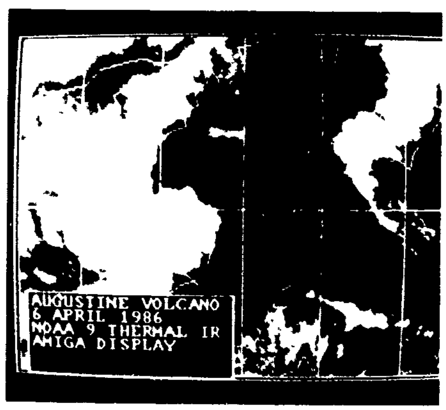
Imagery from space is also used to estimate rainfall during thunderstorms and hurricanes for flash flood warnings. Using GOES satellite data, interactive computer technologies estimate the precipitation amounts associated with severe weather. During Hurricane Diana, for example, calculations indicated nearly 20 inches of rainfall over North Carolina in a 2-day period. Actual rainfall reached 18 inches. Interactive computer technology is also used to estimate snowfall accumulations and overall extent of snow cover. Such data help meteorologists issue winter storm warnings and spring snow melt advisories. Satellite sensors also detect ice fields, and map the movements of sea and lake ice. By also monitoring the southward progression of freezing seasonal temperatures, satellite imagery has often allowed forecasters enough time to warn crop growers to light smudge pots or take other measures to protect crops from damage.

Using GOES Satellite data, IFFA estimates the precipitation amounts associated with severe weather.

Volcanic Monitoring

Far above the surface, satellites provide remarkable views of volcanic eruptions. Both the polar orbiting and GOES satellites monitor eruptions when they occur, allowing scientists to analyze and track dust clouds.

So far, numerous volcanic eruptions have been detected with sensors on polar-orbiting satellites. The satellites send this data to the Smithsonian Scientific Event Alert Network where it is disseminated to the scientific community, federal and state agencies, and foreign countries



Top: Mount St. Helen's shown erupting May 18, 1980.

Above: On April 6, 1986, a polar orbiter took this picture of the Augustine Volcano in Alaska. Such imagery is useful in tracking the ash and dust clouds that spew from volcanic eruptions and in warning aircraft pilots.

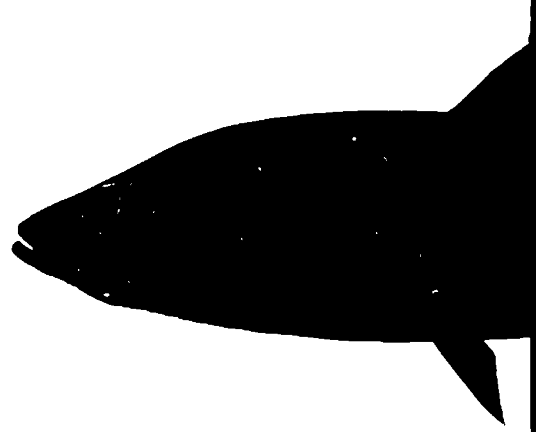
Fire Detection

Blazes can be located by their smoke plumes and the heat registered on infrared sensors. Sensors on both the polar orbiters and the GOES have located wilderness fires in remote and difficult-to-reach areas, enabling emergency forces to better contain the flames.

Oceanography

Large-scale weather patterns are affected by temperatures and currents in the oceans. Polar-orbiting sensors compute some 20–40 thousand global sea temperatures daily. In areas around the United States, these readings reveal ocean currents and features such as the Gulf Stream, its wall and associated eddies, upwellings off the West Coast, and the Gulf of Mexico loop currents.

Ocean surface temperatures help meteorologists study ocean influences on climate. Such an influence is El Niño, a widespread warming of the waters off the west coast of South America. In 1982-83, El Niño and its associated weather-pattern reversal over the coast of South America brought severe flooding to Ecuador and northern Peru, while it left a drought in other areas of the world



Vegetation Index Mapping

Since 1982, NOAA has used satellites to look at the progress of crops and to study vegetation growth. Since 1984, vegetation index maps have been sent to the Weather Service field offices to help farmers monitor the growing season. The multispectral images of the polar-orbiting satellites make this possible

By measuring the greenness of plant chlorophyl, scientists can determine not only the health of crops, but can also pinpoint areas of drought, desert creep, or deforestation the world over. Weather scientists of many developing nations have been trained in this technique under a program conducted by NOAA for the Agency for International Development.

Fisheries

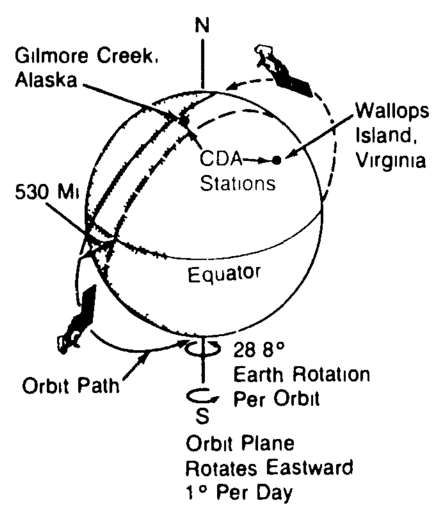
Commercial fishery operations have also benefited from the data supplied by weather satellites. Determining the currents and sea temperatures can help locate schools of tuna or salmon and can assist in tracking the movement of fish eggs and larvae. Satellite data can be used to study hypoxia, a severe lack of oxygen at deep sea levels that can completely block the growth and development of sea life.

Polar-Orbiting Satellites

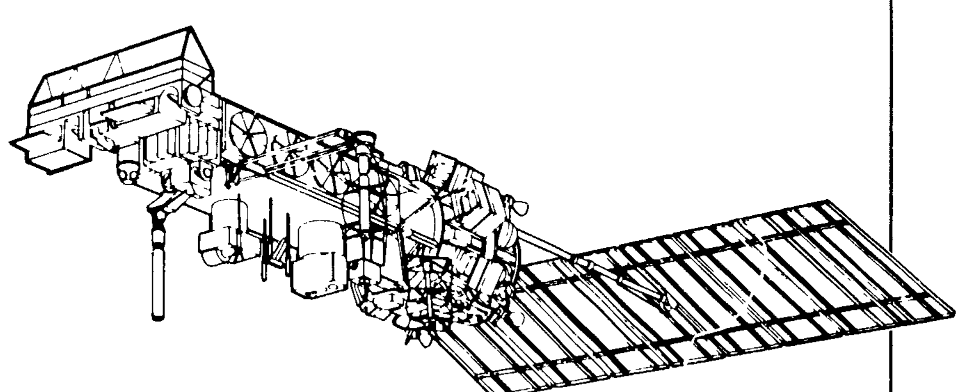
For normal weather coverage, NOAA operates two polar-orbiting satellites. They circle the globe in a north-south orbit, passing over both the North and South poles. One crosses the equator in the morning and the other in the afternoon. They circle in a "Sun-synchronous" orbit of approximately 810 – 850 kilometers, and each observes the entire Earth twice a day. Because they are Sun-synchronous, these satellites circle the Earth so that they cross the equator at the same time daily. The morning satellite crosses southward over the equator at 7:30 am and the afternoon satellite crosses northward at about 2:30 pm. Operating together as a pair, these satellites assure that measurements for any region of the Earth are no more than six hours old.

These polar orbiters provide visible and infrared radiometer data that are used for imaging purposes, radiation measurements, and vertical temperature profiles, and can help calculate water vapor content at several atmospheric levels. They send some 16,000 global measurements daily to NOAA's Weather Service computers, adding valuable information to forecasting models, especially for remote ocean areas, where conventional data are lacking.

NOAA Polar Orbiting Satellites



Advanced TIROS-N (ATN)



Instrumentation Carried By Weather Satellites

Both the polar-orbiting and GOES satellites carry instruments to measure and monitor activities other than weather. For example, they monitor solar winds and flares, and collect and relay data picked up by river and tide gages, seismometers, buoys, ships, airplanes, and automatic weather stations. GOES satellites transmit their data to the National Weather Service as well as directly to amateur and professional users.

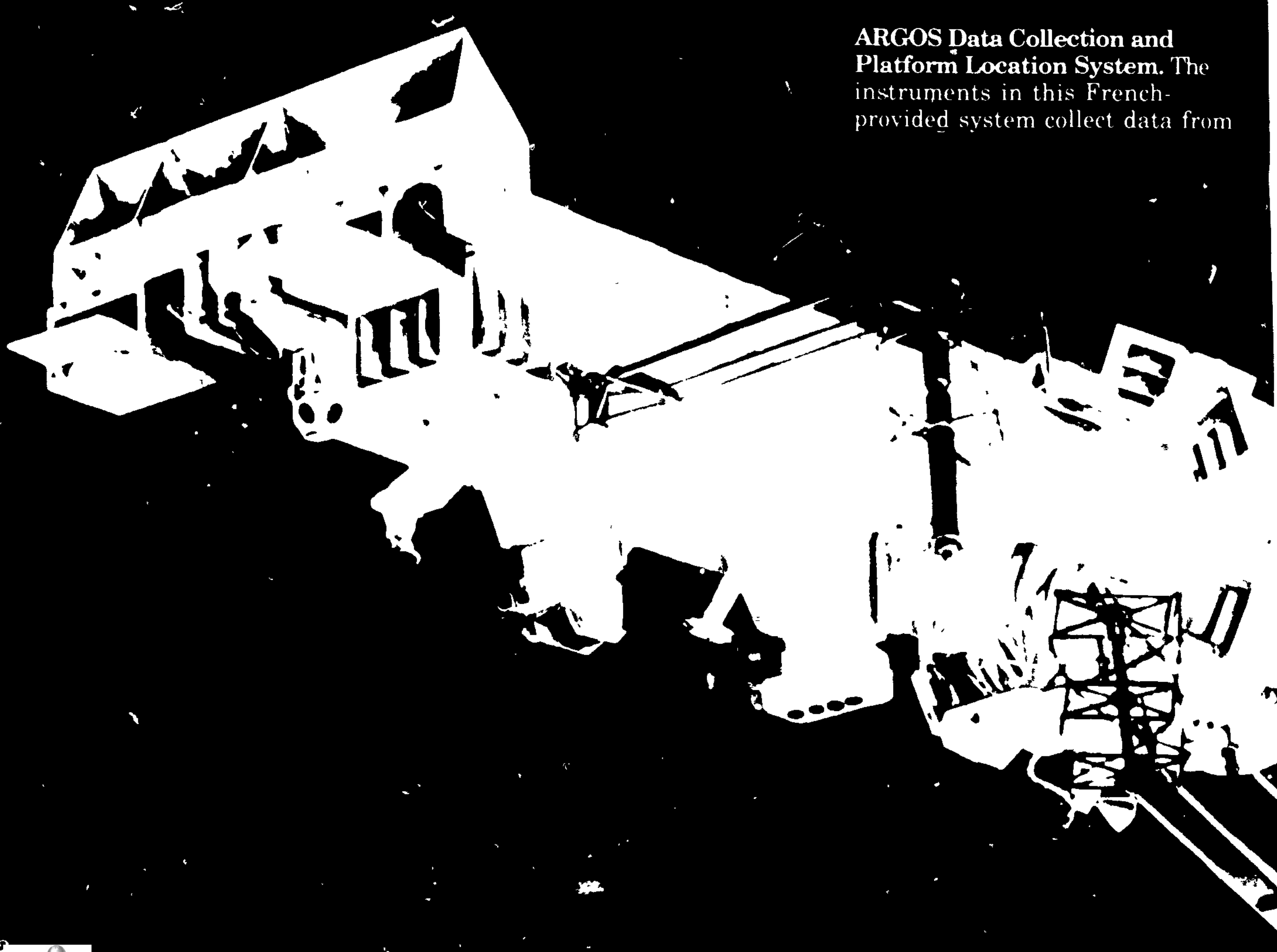
Future GOES satellites will carry improved instruments for concurrent imaging and atmospheric sounding and provide additional information on atmospheric movements of water vapor and the remapping of picture elements to permit better calculation of winds based on cloud motion.

Each polar-orbiting satellite carries six primary systems.

Advanced Very High Resolution Radiometer. This instrument senses clouds over both ocean and land, using the visible and infrared parts of the spectrum. It stores measurements on tape, and later plays them back to NOAA's command and data acquisition stations. The satellites also broadcast in "real time" (this means transmissions are simultaneous with the observations of the instruments). These real-time broadcasts are available in both high-resolution and low-resolution picture images and can be received by anyone in the world equipped with a receiving station. Over the years, such receiving stations have been built and operated by foreign weather services, commercial American weather services, and high schools and colleges throughout the world.

TIROS Operational Vertical Sounder. This instrument combines data from three complementary instrument units to provide temperature and moisture data from the Earth's surface up through the atmosphere.

ARGOS Data Collection and Platform Location System. The instruments in this French-provided system collect data from



sensors placed on fixed and moving platforms, including ships, buoys, and weather balloons, and transmits data to a ground station antenna. Because ARGOS also determines the precise location of these moving sensors, it can serve wildlife managers by monitoring and tracking sensors placed on birds and animals.

Space Environment Monitor. This equipment measures energetic particles emitted by the Sun over essentially the full range of energies and magnetic field variations in the Earth's near-space environment. Readings made by these instruments are invaluable in measuring the Sun's radiation activity.

Search and Rescue Tracking (COSPAS/SARSAT). This system has already proven invaluable in saving human life. Search and rescue transmission equipment on board weather satellites receives emergency signals from persons in distress. The satellites transmit these signals to ground receiving stations in the U.S. and overseas. Signals are forwarded to the nearest rescue coordination center. These centers compute the location of the signals and give a rescue team (usually within a few miles) the coordinates of the emergency site. Both the U.S. and Soviet Union cooperate in the Search and Rescue Tracking system: SARSAT is the American acronym for "Search and Rescue Satellite Assisted Tracking"; COSPAS is the Soviet equivalent.

Earth Radiation Budget Experiment. This instrument is a radiometer. It is designed to measure all radiation striking the Earth as well as all radiation leaving. Such monitoring enables scientists to measure the loss or gain of terrestrial energy to space. Shifts in this energy "budget" affect the Earth's average temperatures, in which even slight changes can affect climatic patterns.

GOES satellites carry four basic sensor systems.

Visible-Infrared Spin-Scan Radiometer and Atmospheric Sounder. This radiometer provides visible infrared and sounding measurements of the Earth. These images, together with images received from the polar-orbiting satellites, are processed on the ground and then radioed back up to the GOES for broadcast in graphic form as a "Weather Facsimile," or WEFAX. WEFAX images are received by ground stations on land as well as on ships. Currently, the GOES WEFAX transmissions are received from western Europe to eastern Australia.

GOES satellites transmit their data to the National Weather Service as well as to amateur and professional users as far away as Australia. There are over 1,000 known WEFAX users who avail themselves of this free service.

Space Environment Monitor. This instrument is almost identical to the sensors aboard the polar orbiters. They measure the condition of the Earth's magnetic field, the solar activity and radiation around the spacecraft, and transmit these data to a central processing facility.

The Data Collection System. Similar to the Data Collection and Platform Location System on the polar orbiters, this system also gathers and relays readings made by sensors placed on various objects (both mobile and stationary) at various locations.

Search and Rescue Transponder. This instrument is carried on GOES East, orbiting at 75° west longitude, and on GOES West, which is located at 135° west longitude. The GOES satellites can relay distress signals at all times, but cannot locate them. Only the low altitude polar-orbiting satellites can compute a signal's location. The two satellites work together to create a search and rescue system, allowing a message to be intercepted by a GOES and relayed even though a polar orbiter may be temporarily outside radio "line of sight." (See "Search and Rescue.")

GOES Satellites

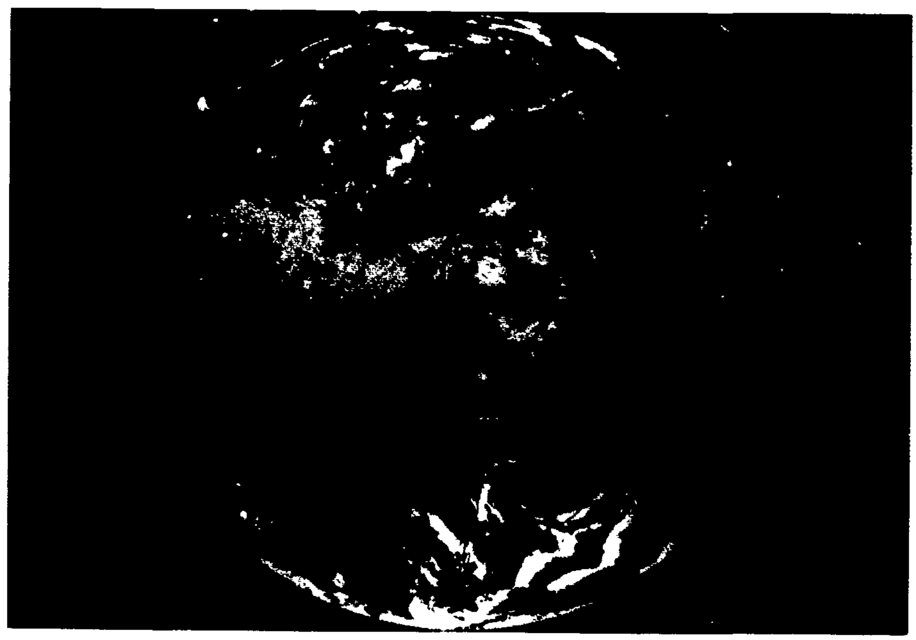
The current Geostationary Operational Environmental Satellite (GOES) system consists of GOES East and West, which orbit at 75° west and 135° west longitude. Each views almost a third of the Earth's surface: GOES East monitors North and South America and most of the Atlantic Ocean, while GOES West looks down at North America and the Pacific Ocean basin. The two operate together to send a full-face picture of the Earth every 30 minutes, day and night. Pictures of smaller areas can be sent more often should a storm need monitoring. These satellites give meteorologists nearly continuous viewing of storms and cloud patterns, as well as measurements of wind fields at cloud altitudes.

The GOES satellites circle the Earth in a "geosynchronous" orbit. This means they orbit the equatorial plane of the Earth at a speed and altitude that allows them to hover continuously over one position on the surface. The geosynchronous plane is about 35,800 kilometers above the Earth, high enough to allow satellites orbiting there a full-disc view of the Earth.

NASA launched the first geostationary weather satellite in 1966 and followed it with another the next year. So far, NASA has placed eight of NOAA's GOES satellites into orbit. Two of these, GOES East and GOES West, are fully operational.

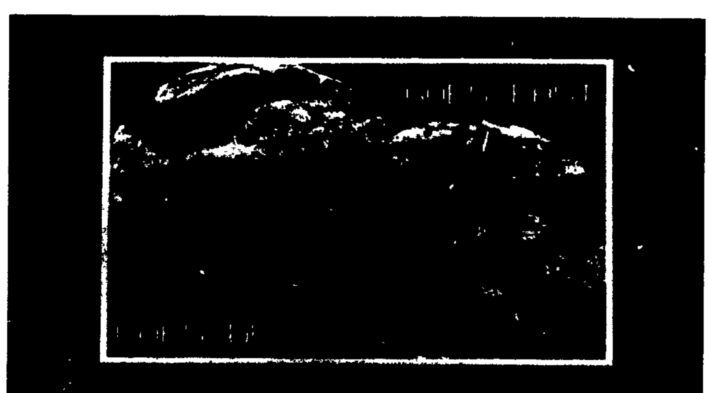
These GOES satellites complement the TIROS polar-orbiting satellites. Both view remote areas and relay their data to instruments at NOAA's ground stations.

By remaining stationed over the same spot both day and night, the GOES can provide the kind of continuous monitoring necessary for intensive data analysis and weather predictions. They look for such catastrophic events as hurricanes, tornadoes, and other severe storms and relay data to ground receiving antennas. These satellites duplicate some of the functions on the polar-orbiting satellites, but from a distant broader perspective, they add the advantage of maintaining a constant vigil.

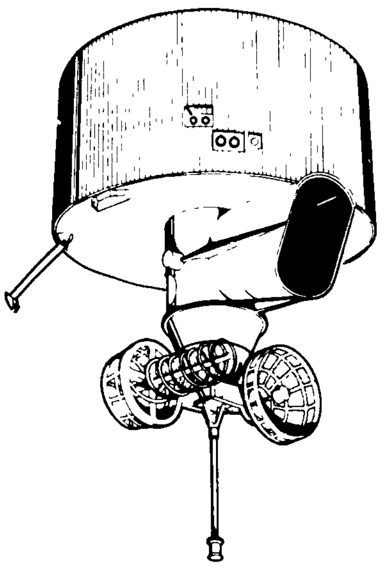


Full-disk view from GOES East. Photo: Courtesy of TASC/WSI

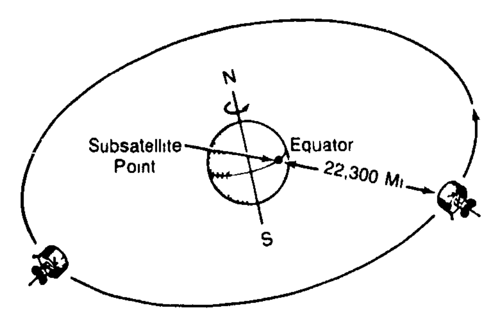
Two GOES satellites observe the eastern and western U.S. and the adjacent ocean areas from a vantage point over the equator. Photo: Courtesy of TASC/WSI



Current NOAA GOES Satellite



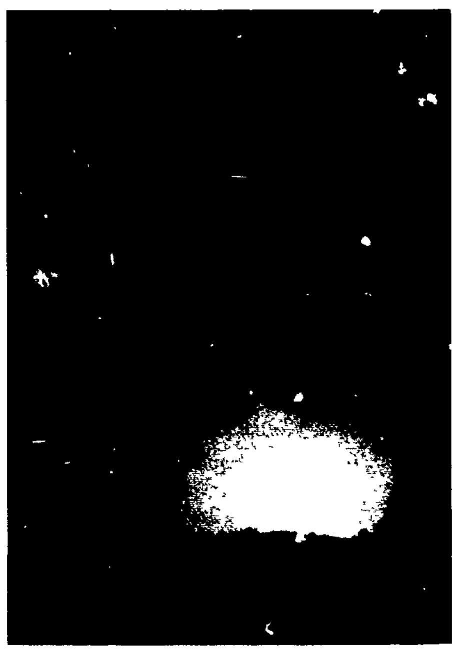
GOES Geostationery Orbit



New Satellites, Sensors, Systems

In the near future, satellite research and applications will resolve a global view of the atmosphere, ocean, and land in unprecedented breadth and depth This will mean a big shift in emphasis for the weather satellite system. Originally driven by space hardware, the system is increasingly being driven by information. Data processing and distribution will get more emphasis as this information explosion develops.

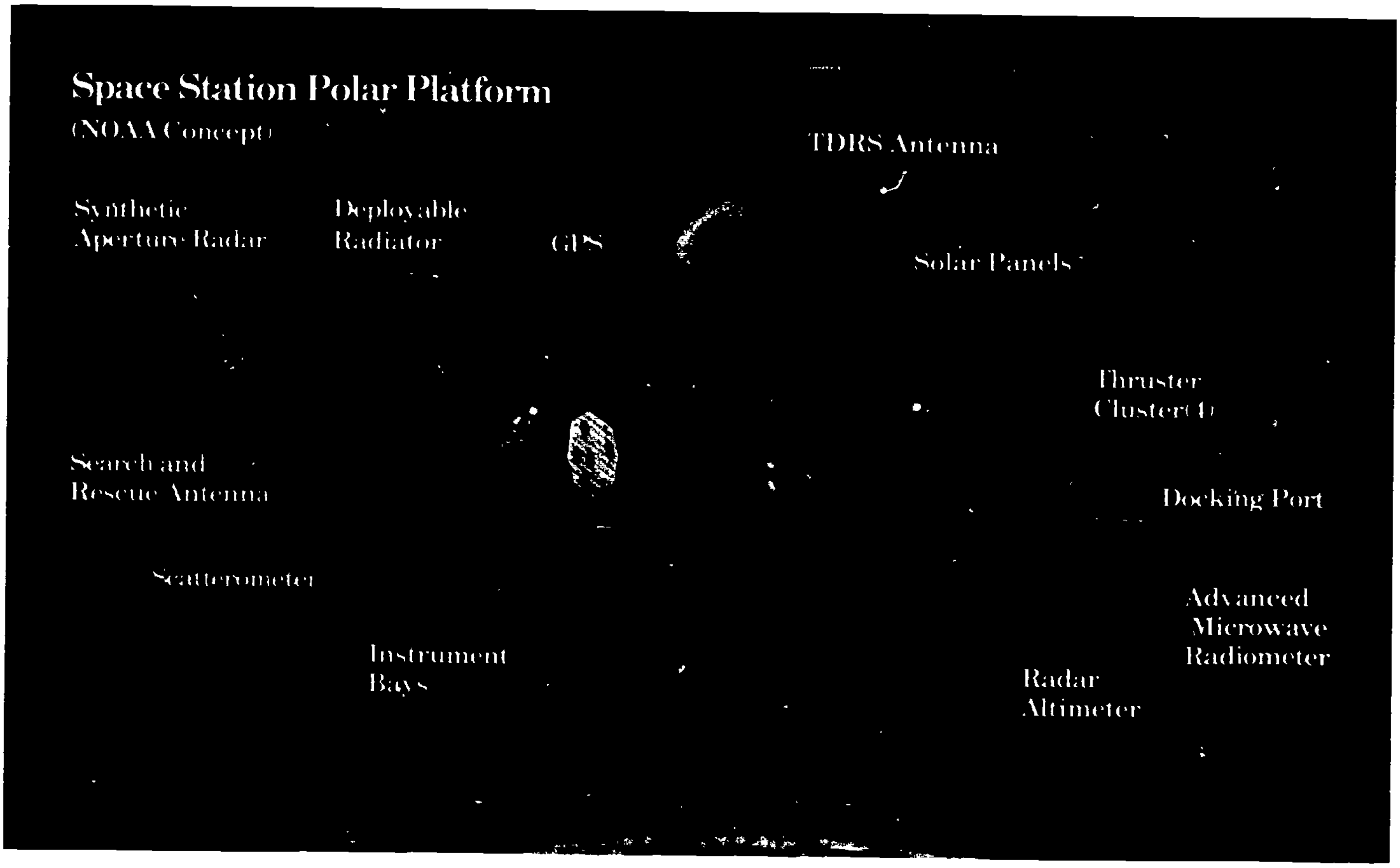
Three new polar-orbiting satellites are to be launched beginning in 1992, carrying a new, eagerly awaited instrument called an Advanced Microwave Sounding Unit For the first time, it will give forecasters global profiles of temperature and moisture inside cloudy regions over the world's oceans and continents The instruments will provide new data every six hours, so that when the satellite passes over an area of severe storms, local forecasters will, for the first time, have information about atmospheric stability close to, and inside, a storm system. This is important in predicting storms because air mass instability feeds tornadoes, hurricanes, and other severe weather conditions.



The next generation of GOES satellites will carry an unusual new sensor that will continuously watch the Sun. This will allow scientists to peer deep into the Sun's surface and study how flares and sunspots affect the weather on Earth.

Five new geostationary satellites of an entirely new design, carrying improved instruments, are to appear at intervals beginning in 1989. For two generations all the GOES spacecraft have been spinning like tops as they move along their orbits. The new GOES will be non-spinning and their instruments will be able to view the Earth continuously, rather than "eyeing" a scene once with each revolution. Both the satellite and its solar photovoltaic-panel powerplant will be larger.

This new design is expected to improve dramatically the performance of both imagers and sounders. When this new satellite appears it will no longer be necessary to turn off a sounder while an imager is operating. An unusual new sensor will constantly take pictures of the Sun,



detecting solar X-rays. This will enable scientists to peer deeper into the Sun's surface to spot energy flares that can affect Earth's weather.

Another new sensor will observe lightning flashes on Earth. By counting these flashes, scientists hope to learn more about how electrical exchange affects weather.

For the period into the 21st century and beyond, plans are being drawn by NASA and NOAA for astronaut-tended, polar-orbiting meteorological platforms. These will function as part of NASA's Space Station. Whereas present weather satellites have life expectancies of only a few years, the repairable platforms are expected to last for many years.

NASA plans a serviceable geostationary platform for early in the 21st century Discussion of a project to develop a microwave sounder for geostationary flight is already in progress. Planners anticipate that many "active" instruments will join the array of existing sensors. Active instruments, such as radar, send out a pulse or series of pulses to "illuminate an area of interest." A wind sensor using laser pulses is another potential gain for forecasters.

Already weather satellites present an excellent example of international cooperation in space. In the years ahead, many more nations are expected to participate in weather satellite programs.

Definitions

Radiometer–A satellite instrument that measures radiation (reflected sunlight and heat, or thermal radiation).

Sounder–A special kind of radiometer which measures changes of atmospheric temperature with height, and changes in water vapor content of the air at various levels.

Imager–A satellite instrument that measures and maps sea-surface temperatures, cloudtop temperatures, and land temperatures. Imager data are converted by computer into pictures.

Infrared–Only a small part of the electro-magnetic "spectrum" is visible to us as light. The rest of it can be sensed as heat, or infrared radiation. Infrared sensors serve as satellite "eyes" during periods of darkness.

Remapping–When the spherical Earth is photographed by satellites, areas lying near the outer edge of the picture are distorted. Remapping is done to flatten the Earth into a standard projection.

Resolution–The value of a telephoto lens is permitting the photographer to get a larger picture of the subject (sharper resolution) but less of the surroundings. It's the same with satellites. Resolution of today's satellite "picture elements" ("pixels") can vary from 10 meters (30 feet) for surveying uses to 1 km (3000 feet) for weather satellites.

WEFAX–Telegraphic abbreviation for "weather facsimile," a system for transmitting via radio visual reproductions of weather forecast maps, temperature summaries, cloud analyses, etc. Most of these WEFAX transmissions are relayed by GOES spacecraft today.

Platforms–Weather satellites are often called "space platforms" because they serve as emplacements in space for various instrument systems. The same term is applied to automatic weather data transmitters installed on buoys, balloons, ships, and planes, and mounted in remote areas. Weather satellites collect this data and feed it ...

El Niño –A warming of the surface waters of the eastern equatorial Pacific that occurs at irregular intervals of 2 to 7 years and lasts for 1 to 2 years. The Southern Oscillation is a global-scale seesaw in atmospheric pressure between Indonesia-North Australia, and the southeast Pacific. Together, they are interacting parts of a single global system of climate fluctuations popularly known as ENSO–The El Niño/Southern Oscillation, so named because it first was associated with Christmas, the time of the Christ Child.

Nephanalysis–Using cloud pictures to study the relationship between cloud forms and storm centers. In classical mythology Nephele was a woman Zeus formed from a cloud.

NASA
National Aeronautics and
Space Administration

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE