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ABSTRACT

This booklet is one in a series of instructional aids designed for use by elementary and secondary school science teachers. It reviews how the various forms of remote sensing can provide invaluable knowledge about the earth as the need for environmental information continues to increase. Remote sensing involves space photography, infrared imagery, and radar imagery, all of which are discussed and represented by example photographs made by these techniques. Nearly 60 uses of remote sensing are listed, including the detection of plant disease, weather studies and predictions, detection of air pollution, water pollution, thermal pollution, and the locating of water and energy resources. An annotated list of resource materials is provided. (PR)

NATIONAL SCIENCE TEACHERS ASSOCIATION

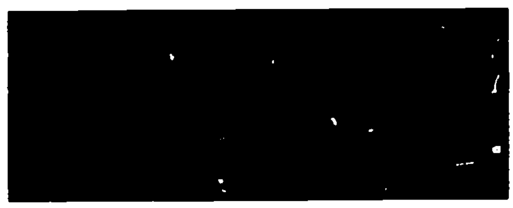
how to

How To Study the Earth From Space

Robert E. Boyer *Professor, Department of Geological Sciences*
The University of Texas at Austin

THE SPACE AGE IN THE CLASSROOM

Just 20 years ago, classroom use of aerial photographs taken by conventional aircraft was a novelty. However, appreciation of aerial photographs as a learning tool in conservation, geography, geology, and earth science courses soon grew rapidly. Viewing aerial photographs in stereo pairs has aided many students to appreciate the relief and configuration of the land surface. For some, it has been the only "escape" from the confines of their small world.



The following pictures or others that can be obtained from the organizations mentioned in the Source List, can be combined in many ways for teaching, enrichment, for open-ended assignments, or for independent study by the students.

Space photography and imagery from remote sensors now offer a great deal more! Already aspects of these techniques are being included in textbooks, and the importance of "pictures" from space as an aid to classroom activities will increase greatly in the next few years. The chart on page 10 lists the many subjects for which satellite data will provide a greater understanding. As concern for our environment mounts, the role of information obtained from satellites will become ever more important – in the newspapers, on television, and in the daily living of each person.

Demands for more abundant supplies of energy, especially for our rapidly expanding metropolitan areas; the need for more and more water for agriculture, drinking, and the myriad other uses of water; the desire to curb pollution and clean up our lakes, rivers, and shorelines; the necessity to utilize our land more efficiently for living, working, and recreation; the opportunity to detect diseased plants and trees in orchards and forests – all these and numerous other aspects of our environment can be aided through photography from space.

Take advantage of the information obtained in the space age by launching into the use of satellite pictures as they become progressively more available for classroom use.

A VIEW OF EARTH FROM SPACE

The air was dry and the skies clear on November 14, 1966, when Lt. Col. Edwin E. Aldrin, Jr., photographed the Texas and Louisiana coasts during the flight of

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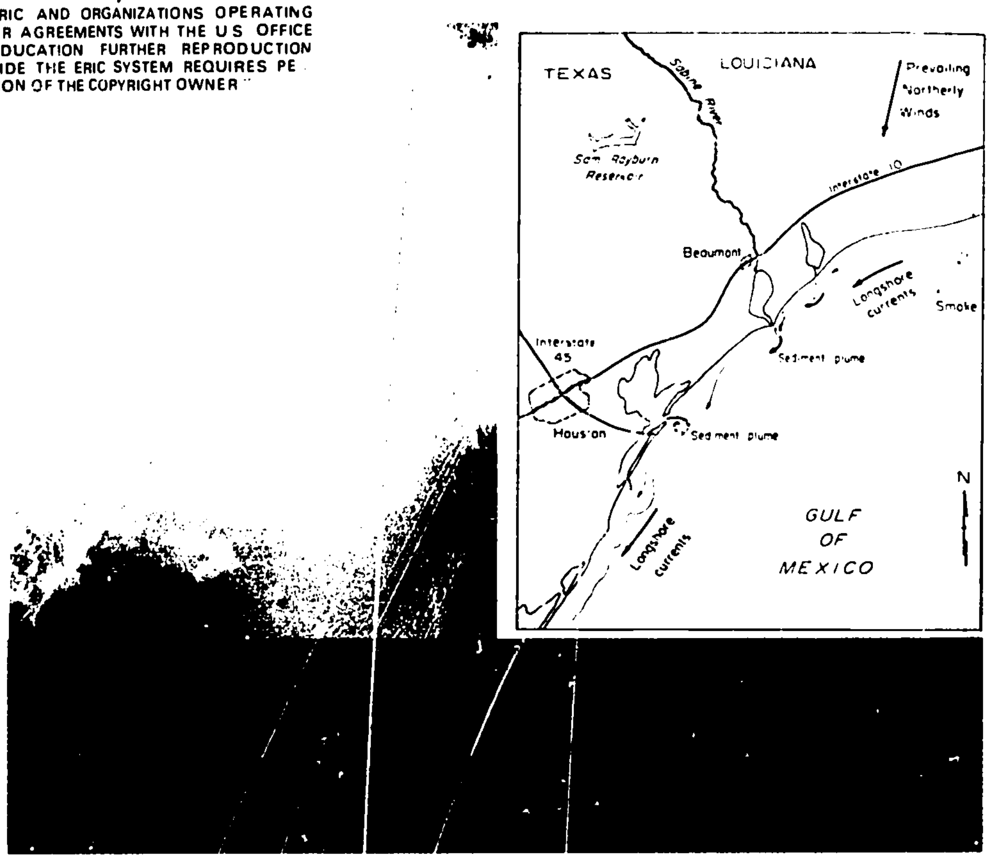


Gemini XII. The record of strong northeast winds is seen by the seaward drift of smoke from a marsh fire along the Louisiana coast and by the southwest flow of coastal currents. Lighter colored, sediment-laden water flows out of the inlets, and great eddies extend across the shallow shelf. The major drainage systems flowing into the Gulf, the network of main highways, and the cities and towns along the coast are readily observed. All of these features are visible on a single photograph!

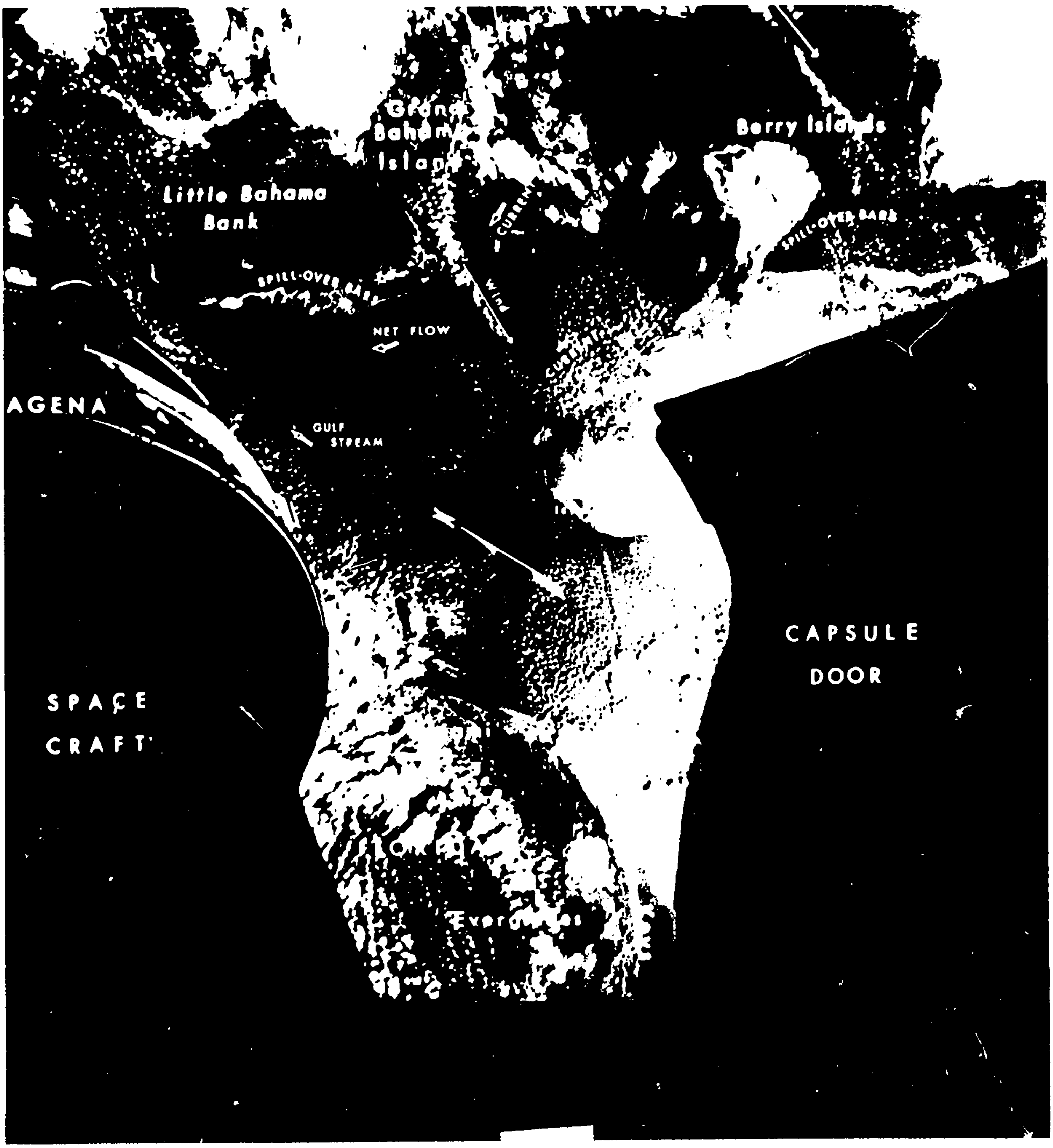
Do the oceans hold the key to our future needs for food, water, and mineral resources? Man has traveled over 385,000 kilometers to walk on the moon but has never traversed the ocean floor, although it is only a little over 11 kilometers from the surface to the deepest parts. Photographs from space will aid oceanographers as they seek to conquer this lone frontier and harvest its crops. This new tool allows a view of land-sea-air interactions of major natural processes on a scale never observed before. Much attention will focus on the coasts because this is where man is most intimately involved with the sea. Along the shorelines is where ocean pollution is most likely to occur. The bays, estuaries, and lagoons serve as the spawning grounds for much of the marine life. Thus this narrow zone where water meets land is of critical importance to the ecological balance of the system.

The United States is undergoing a dynamic shift in the distribution of its population. By the year 2000, it is estimated that 80 percent of the people will live in major urban regions, posing great demands on the land areas involved. Urban planners and other decision-makers for the cities must have a clear understanding of the natural systems involved if they are to meet the demands placed on them as metropolitan areas swell.

We have reached the environmental crossroads between the need for huge amounts of resources on the one hand and the necessity to prevent contamination, pollution, and general deterioration of the land on the other. Space photography is destined to play a major role in solving this crisis. Not only can single urban areas be analyzed in total on these photographs, but interconnecting metropolitan areas like the "Northeast Corridor" from Boston to Baltimore can be viewed clearly. In this way urban land uses can be monitored as the population sprawl takes place. Patterns of growth can be quickly established and their trends modified to suit the environment best. A close regulation of the transportation and drainage networks of the cities can also be readily established with the aid of space photography.

CONTINUOUS ORBITING SATELLITES

Project EROS (Earth Resources Observation Systems) illustrates the importance of space photography to this nation's future well-being. In the EROS program, unmanned satellites, called the Earth Resources Technology Satellites (ERTS), are scheduled to orbit the earth and monitor its features from space through a battery of conventional cameras and remote-sensing devices. Repetitive televised images of the earth's surface will be relayed to receiving stations where rapid sorting and analysis can be made. EROS will serve a wide variety of data users including (1) environmental scientists, (2) resource managers and planners, (3) policy-makers, (4) the resource-producing public, and (5) educators. The broad overview



from space provided by the ERTS satellites will permit gross inventories of the environment and yield valuable information on hydrologic, geologic, geographic, and land-use activities.

For the first time, comparable observations can be made all over the world. Such global coverage will provide a uniquely new perspective. Availability of this worldwide information, including areas normally inaccessible, will accelerate all types of mapping. Detailed pictures of atmospheric patterns and their changes will provide information for more accurate weather forecasting. Storms will be followed more closely, allowing greater opportunity to avoid natural disasters.

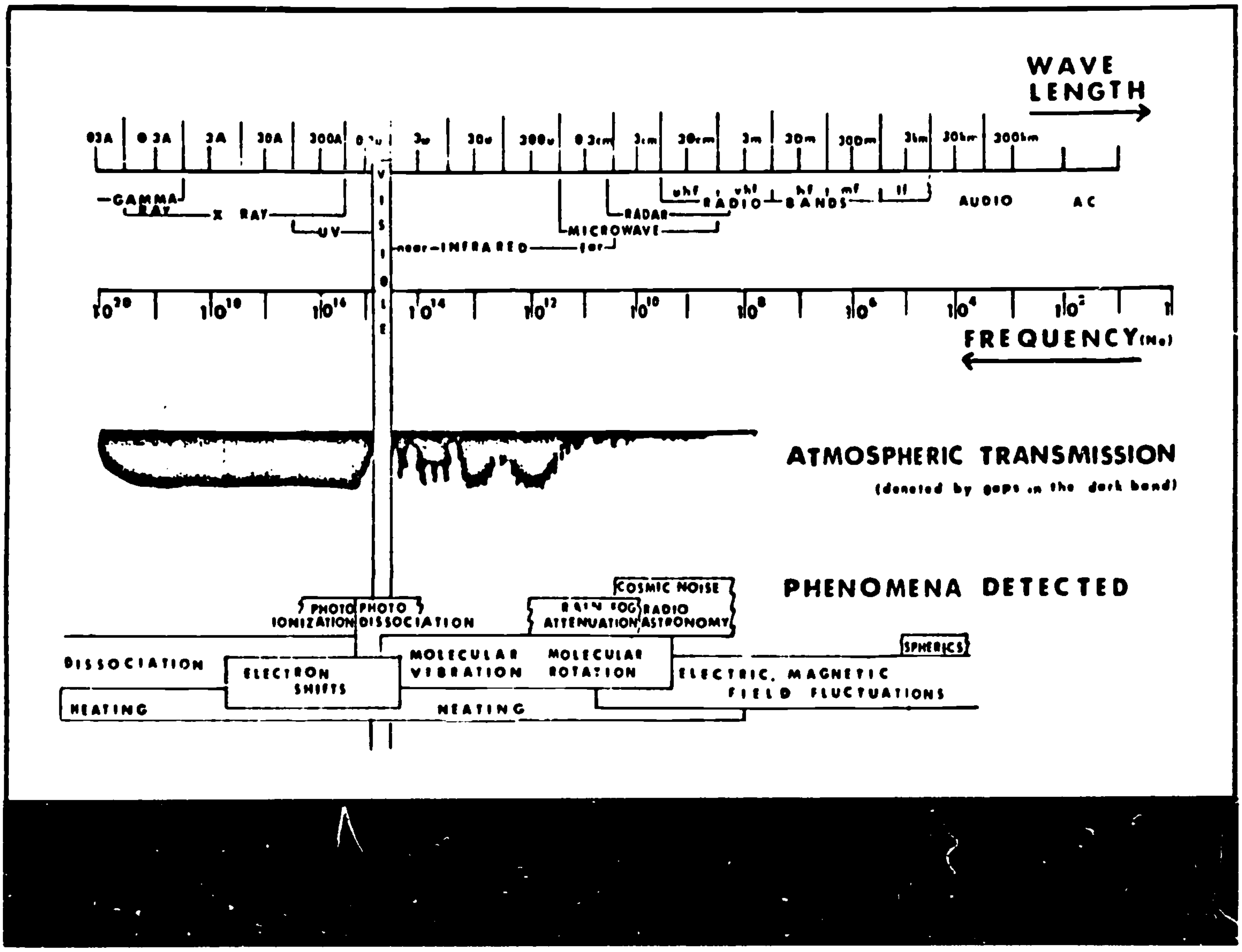
The sequential photographic coverage will enable development of detailed water-flow patterns within large bodies of water, such as Lake Michigan and the Mediterranean Sea. In this manner the rate of influx and distribution of sediments can be quickly understood. Likewise, ocean-current patterns and their changes can be monitored and their effects on fishing and on coastal regions rapidly identified.

Many pending dangers, both natural and created by man, can be more effectively monitored. These include the prediction of earthquakes, observation of volcanoes, inventory of forests and wildlife threatened by hazardous weather conditions or fire, measurement and mapping of radiation levels and pollution concentrations in the air, and quicker prediction of potential floods through more accurate and current records of rainfall and snow levels.

OUTSIDE THE VISIBLE-LIGHT SPECTRUM

The potentialities of space photography are not limited to taking pictures at greater distances from earth, although this is indeed an important feature. Man has become increasingly aware of the vast knowledge to be gained by viewing features on earth through the wavelengths other than light visible to the naked eye. Unlike the space age, this story began centuries ago when Sir Isaac Newton pondered the nature of light itself. By using a prism, Newton divided visible light into a "spectrum of colors," and the different colors were then attributed to variations in the *wavelength* of the light. This wavelength theory is still applied today although scientists also consider light as a stream of particles, with each particle containing a distinct amount (quantum) of energy.

By the nineteenth century, experiments were being conducted to detect wavelengths of light outside the visible spectrum. Thus X-rays, with wavelengths shorter than those of visible light, and radio waves, with considerably longer wavelengths, were discovered and recorded by special equipment. Scientists now realize that visible light is restricted to a very narrow band of wavelengths within the total electromagnetic spectrum (see illustration). And many parts of the total spectrum are now receiving careful study as *remote sensing* (not visible to the naked eye) becomes more and more useful.



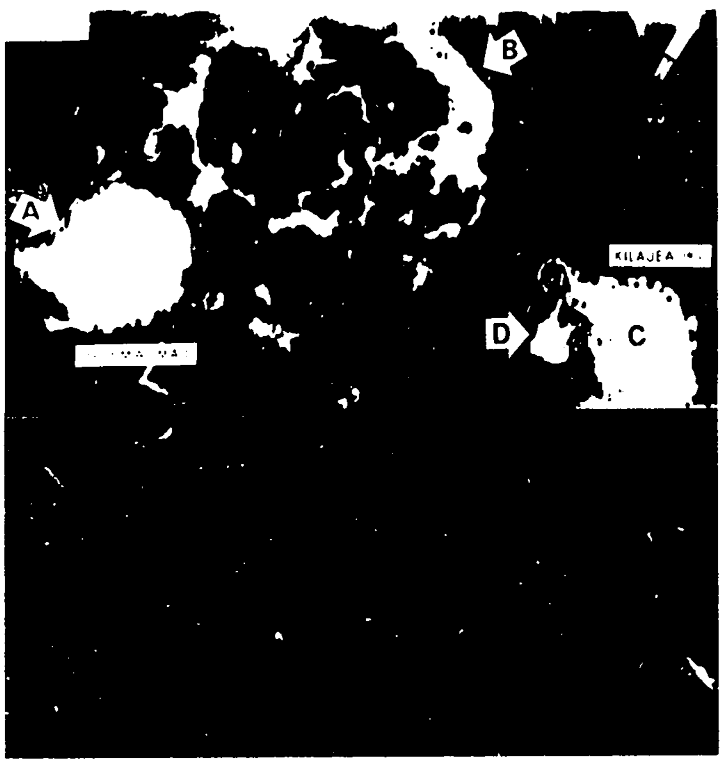
Wavelength is controlled by the rate of vibration, called *frequency*, of the waves. Frequency is the number of times a second the wave is sent into the air; the more frequently it is sent out, the shorter the wavelength. Improved remote sensors detect more accurately the patterns of these different wavelengths. In this way many special capabilities of these waves are being discovered. Some uses are well known whereas others await man's genius to be applied. For example, modern medicine could not have achieved the present level of help to the sick without X-rays, which penetrate the body and outline the structure of bones, internal organs, and teeth. Likewise, worldwide communication systems, including television, are based on the use of radio waves and the control of their frequencies.

THE ROLE OF HEAT IN IMAGERY

Waves propagated at frequencies just slightly lower than visible light can be detected by the heat they give off. This wavelength range just beyond the red end of the color spectrum is known as *infrared* (IR). Using heat-sensitive film, an image of the features is recorded by a scanning device, based on the amount of heat these features emit. The resulting images, such as those shown on the following page, are useful for a wide variety of possible purposes.

As our country searches for additional energy sources, the uses of steam and other geothermal power become more important. The earth is a tremendous heat reservoir; from "hot spots" near the surface hot water and steam can be extracted through drill holes. Sites of volcanic activity within the past few million years are especially promising as potential sources. This is true of the western United States, particularly along the Pacific Coast, which holds great promise for geothermal energy. The Geysers area, located about 120 kilometers north of San Francisco, has produced steam for the past 12 years for the generation of electricity. Through infrared imagery, it is possible to survey the distribution of thermal concentrations such as The Geysers area and by this means locate new power sources.

Some types of chemicals and other waste products of man's industrial world, when added to parts of our water system – e.g., piped into lakes and streams or dumped into bays, estuaries, and rivers – affect the normal temperature patterns of the water. Known as "thermal pollution," this may alter the amount of oxygen available in the water or kill temperature-sensitive plants and animals which live there. Thus the food chain of the whole system may be affected, causing the death of important species of water life. Hotter water shows up

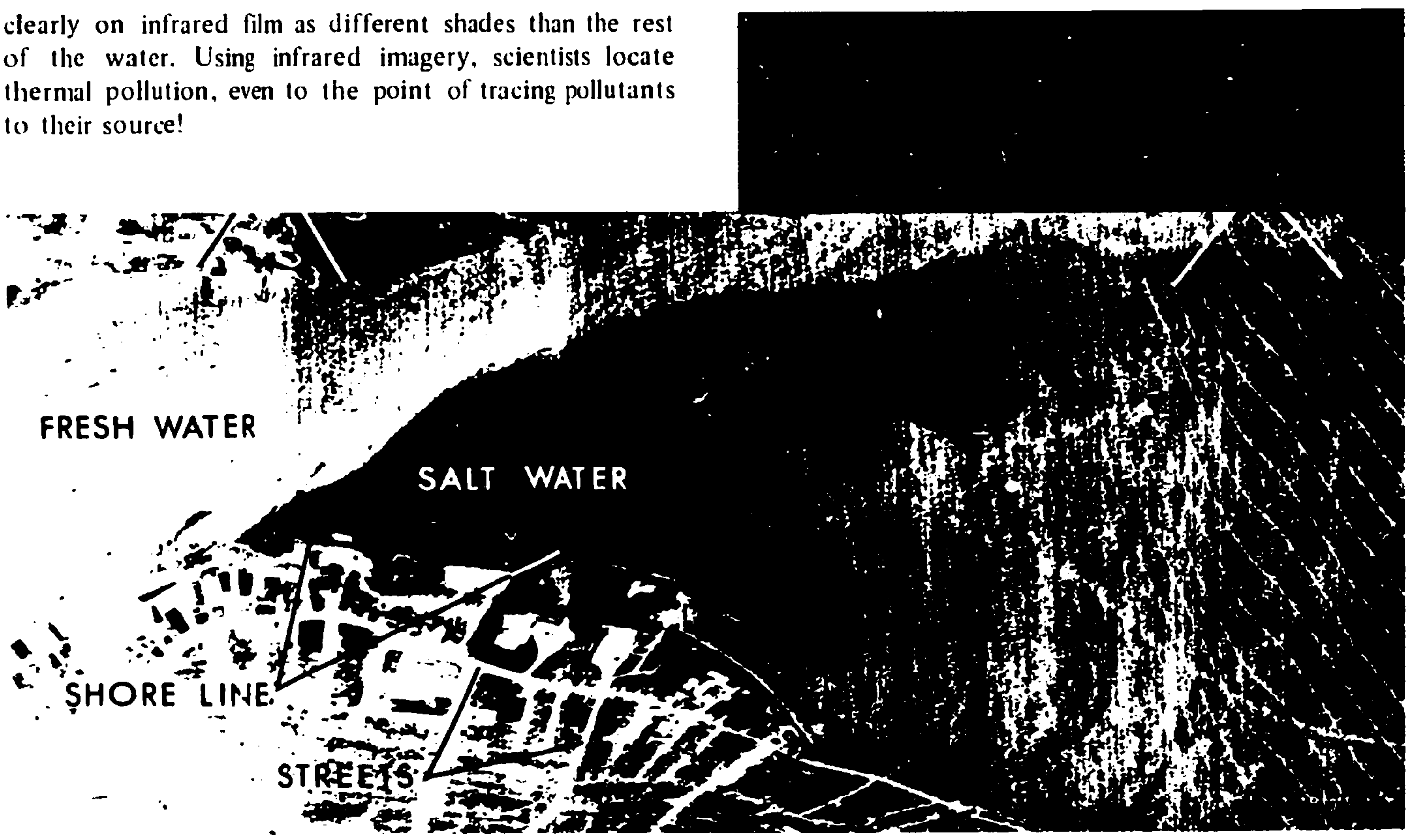


When trees or crops first begin to lose their vigor and before they can readily be detected as unhealthy by ground inspection, subtle changes take place in their heat reflectance. Conventional photography does not reveal a change in their condition, but infrared film registers these slight variations in the heat given off by the leaves. The diseased plants appear darker on the print than do healthy ones. In this way unhealthy plants on a farm or in an orchard – blight on potatoes, fungus on fruit trees, rust in oats and wheat – can be detected and accurately located. Through this technique diseases may be caught early enough to save the plant life involved; if not, the diseased plants can be removed before other plants are affected. The photograph on the opposite page shows an example of an infared print of vegetation.

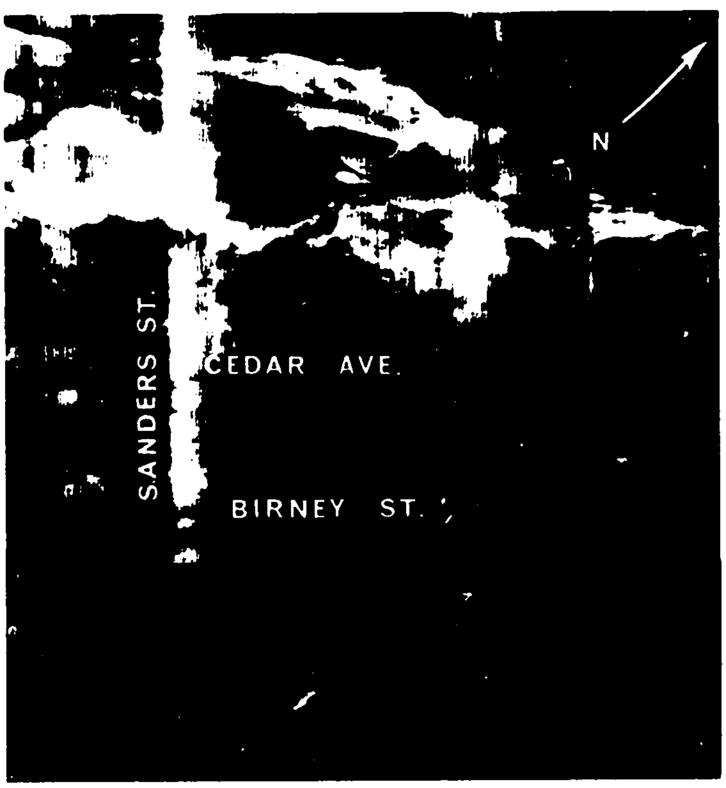
EXPLORING RESOURCES

A glance at a map showing the population distribution in the United States reveals the cluster of cities along the coasts. As the population of urban environments swells, this density will increase. Thus water along the shorelines, as well as inland, looms as a greater and greater concern. Infrared imagery may play a major role in finding the freshwater which seeps underground on the land surface and then "leaks out" into the oceans. These cold-water upwellings are an important source of water supply. Scientists from the U.S. Geological Survey have been successful in identifying more than 200 freshwater springs flowing into the Pacific Ocean from the Island of Hawaii in this manner. Likewise, tracing currents in the oceans may prove extremely helpful in locating schools of commercial fish. Both water and food sources of the future may be closely linked in this way to our space program.

clearly on infrared film as different shades than the rest of the water. Using infrared imagery, scientists locate thermal pollution, even to the point of tracing pollutants to their source!



These examples illustrate a few of the many possible applications of infrared imagery to man and his environment. Doubtless you can think of others!



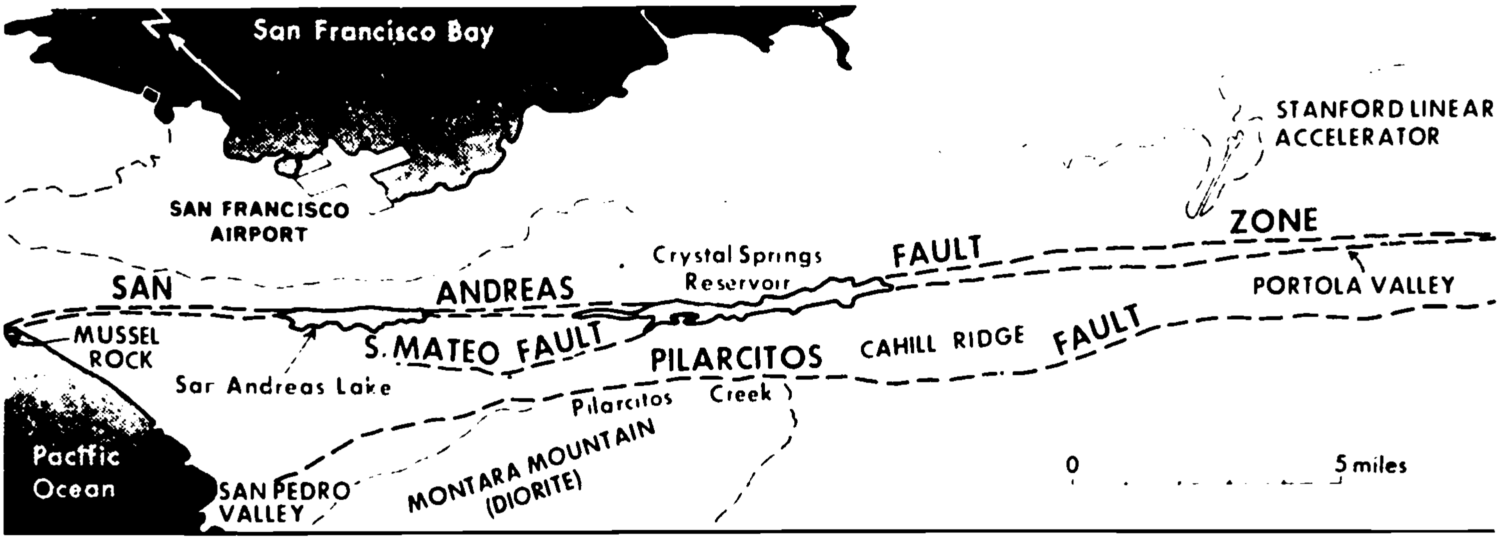
AN EYE IN THE DARK

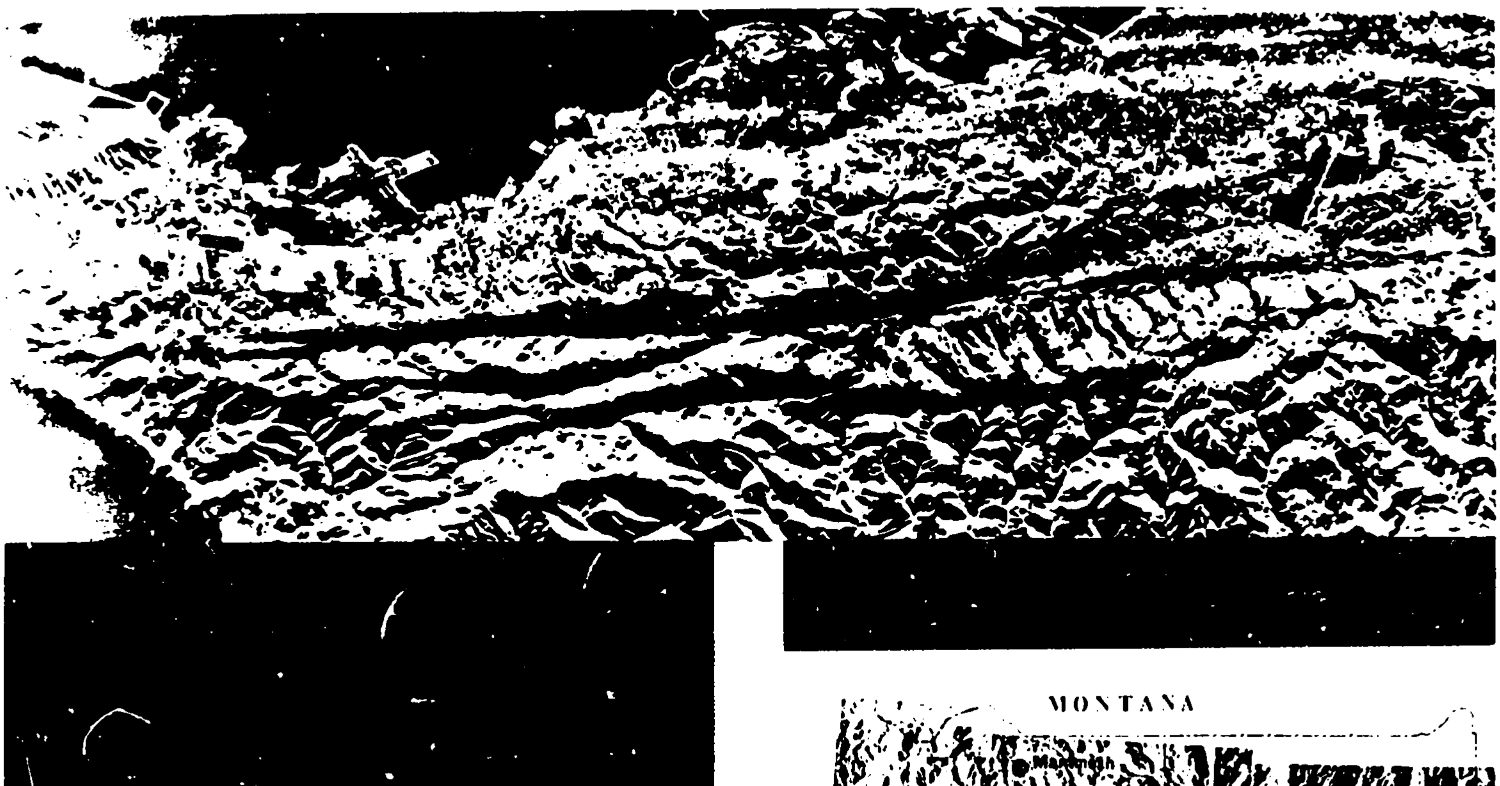
Airplanes are able to find their way through dense fog to land safely because of *radar*. It enables "seeing" for hundreds of kilometers despite clouds, rainstorms, smog, and darkness. Indeed, national defense since World War II is based on radar to direct missiles, detect enemy craft, and prevent surprise attack. Put to use more recently as an eye focused on the earth's surface, radar's penetrating ability makes it valuable in many ways.

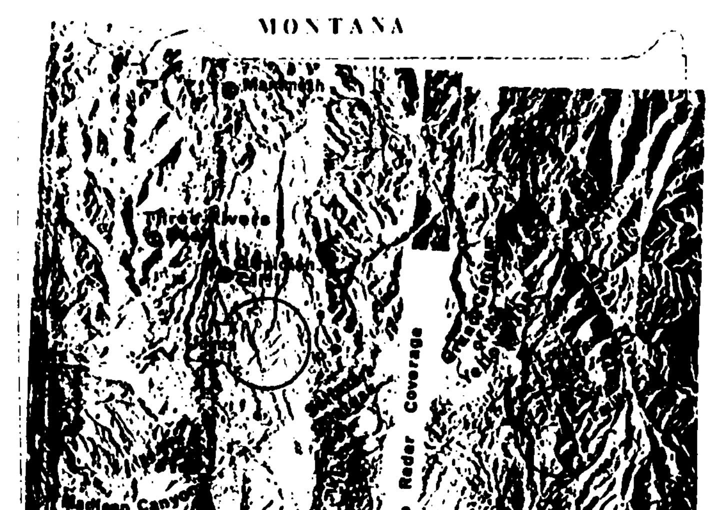
The wavelengths of radar have frequencies even lower than infrared. Side-looking airborne radar, known as SLAR, is installed on aircraft and space vehicles. Short, intense pulses of radio waves are sent out, intersect the landscape, and return as echoes where they are received by an antenna and recorded on a screen – much in the way a bat uses echoes to avoid obstacles when flying. The distances of features on the landscape are recognized on the image by the time it takes for the echoes to return. Density variations on the film are a response to the brightness of the radar signal coming from the ground. Thus variations in the smoothness of objects are detected and recorded by radar. The high-quality contrast of the radar image results from the ability to reveal certain features more clearly than others.

SLAR is especially useful in areas obscured a great deal of the time by adverse weather conditions. The ability of radar waves to pass through cloud cover permits scanning at times (including at night) when conventional photography would be of no value. Radar was used in 1965 to produce imagery of a large segment of Panama which is almost perpetually cloud covered. This provided the first complete view of the Darien Province of Panama, and the imagery is now being used extensively by scientists to study the drainage patterns, surface configuration, vegetation types, and engineering geology of the area.

Many densely forested areas like Panama may contain valuable mineral resources locked in the rocks hidden by soil and vegetation. Although prospectors trekked through much of the brush on their trusty burros, they relied mainly on the rocks for discoveries. Trained geologists have been likewise handicapped by the obscured land surface. Radar can penetrate the vegetation of heavily forested areas, revealing the bedrock geology.







Differences in the relative roughness of surface texture on radar images help earth scientists distinguish between various rock structures, bedrock, and soil. A radar map of Yellowstone National Park was prepared by scientists of the U.S. Geological Survey as an experimental product to establish the value of this tool. A SLAR system provided nearly total coverage of the 2¼-million-acre park. The map was compiled by piecing together 10 radar flight strips. The strong-shadow effects provided by the radar imagery emphasized the topography and enhanced bedrock patterns. The map outlines lava flows, rock-fracture trends, and deposits formed thousands of years ago when glaciers existed in the area. Obsidian Cliff, Madison Canyon, Pitchstone Plateau, Heart Lake, and even the Continental Divide, are examples of topographic features readily identified. The success of this project assures extensive mapping with radar in the future. It will be of special value in isolated areas of the world.

Radar may also be an aid to solving our needs for water. It has helped in locating and outlining earth faults and other fractures, for mapping of geologic rock types, and for classifying the roughness of the ground surface. All these features are closely related to the effectiveness of ground-water recharge and the movement of ground water. Thus, as demands on our water supply increase and further concern is placed on the sizes of watersheds and the location of future reservoirs, radar will play a vital role in the decision-making.

EARTH RESOURCES OBSERVATION SYSTEMS

[illegible] of the "Seventies" through the EROS program. Additional [illegible] will develop as the technology improves. (List compiled from EROS publications.)

Agricultural Operations
- Agricultural census
- Crop prediction and control
- Detection of disease or insect damage
- Drought prediction

Aids to Shipping
- Measurement of condition of sea
- Reconnaissance for sea ice
- Sea rescue
- Ship routing and tracking

Air Pollution
- Atmospheric anomalies of mercury, iodine, and sulfur dioxide as prospecting aids
- Monitor nitrozone concentration

Cartography
- Map preparation
- [illegible]

[illegible]

- Soil conservation studies
- Studies of agricultural productivity, growth process

Forest Resources
- Forest inventory
- Protection against forest fires, early detection, surveillance

Geographic Studies
- Inventory of [illegible]
- Land-use studies (current distribution, trends, patterns)
- Measurements guide for level of economic activity
- Physiography of remote areas
- Population estimates
- Transportation network

Mineral Resources
- [illegible]
- [illegible]

Water [illegible]
- [illegible]

ANNOTATED SOURCE LIST

Books, Periodicals

1. Colwell, Robert N. "Taking Inventory of Croplands and Wildlands." *The Science Teacher* Vol. 37, No. 4, April 1970.

   Describes the need for improved resource inventories leading to improved resource management through use of aerial and space photography.

2. Colwell, Robert N. "Remote Sensing of Natural Resources," *Scientific American* Vol. 218, No. 1, January 1968.

   The uses of remote sensors including gamma-ray detectors, infrared, multiband cameras, and radar to examine agricultural crops and forests to detect diseases, locate fires, and regulate uses of our natural resources.

3. Lowman, Paul D., Jr. "The Earth from Orbit." *National Geographic Magazine* Vol. 130, No. 5, November 1966.

An overview of the wealth of knowledge about earth obtained by color space photography. The new perspective of seeing vast areas on single photographs is especially useful.

4. Matthews, William III. "A New View of an Old Planet." Chapter 6 in *Science Probes the Earth*. Sterling Publishing Co., Inc., N.Y. 1969.

This chapter provides a stimulating summary of the current technology of man's investigation of earth from space.

5. Nicks, Oran W., Editor. *This Island Earth*. NASA SP-250. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 1971. $6.

A collection of photographs taken from space, with excellent scientific information added, in a book designed to help illuminate man's place in the universe.

6. Stevenson, Robert E. "View of the Earth from Space." *Journal of Geological Education* Vol. 16, No. 3, June 1968.

A focus on the coasts, showing how space photography can be used to study shoreline processes. The importance of this "tool" in man's fight against pollution of the spawning grounds of marine life – the bays and estuaries – is emphasized.

Chart

The Electromagnetic Spectrum compiled by Westinghouse Research Laboratories, Westinghouse Electric Corporation, Printing Division, Trafford, Pa. 29" x 41". 1961. $3.50.

An attractive multicolored chart designed for hanging; illustrates the main types of waves, their wavelengths, and their uses.

Film

The View from Space. (Parts I & II), McGraw-Hill Films, New York. 1969.

This color, sound film (50 minutes: 2 parts) documents the values of the space program to man through the potential knowledge to be gained about earth.

Photographs, Slides

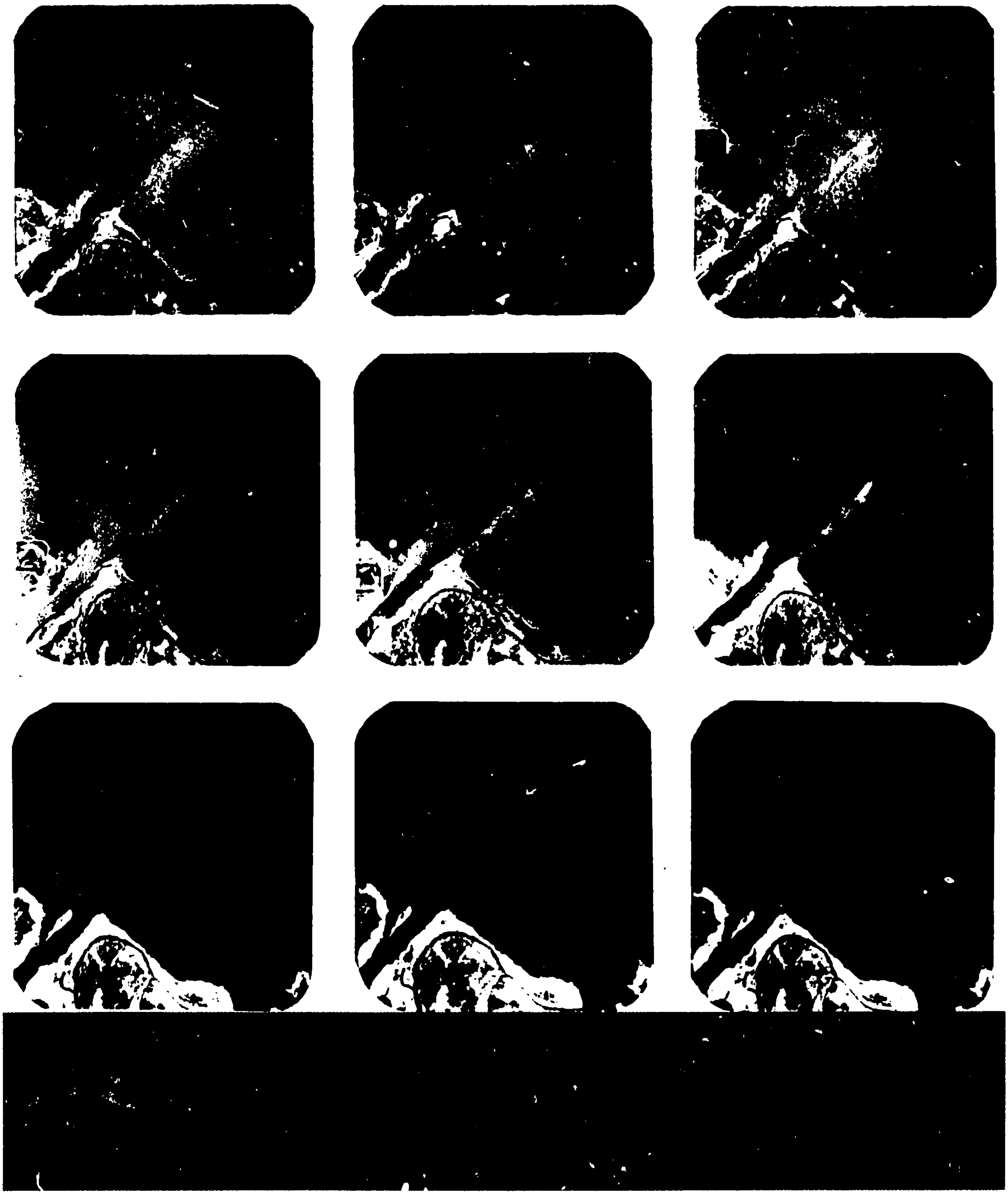
The Technology Application Center, University of New Mexico, acts as the distribution center for photographs of space flights of the National Aeronautics and Space Administration (NASA). Catalogs of available photographs from the Gemini and Apollo flights can be obtained from the Center (Box 181, Albuquerque, New Mexico 87106). Sets of 35-mm color slides obtained from Gemini and Apollo photography are also available for classroom teaching purposes. These slide sets are arranged by subject matter for convenience in their ordering and use. Subject headings of these sets include: geography, geology, hydrology, meteorology, oceanography, and land use and urban studies.

U.S. National Aeronautics and Space Administration. *Earth Photographs from Gemini VI through XII*, (NASA SP-171), U.S. Government Printing Office, Washington, D.C. 327 pp. 1968.

U.S. National Aeronautics and Space Administration. *Earth Photographs from Gemini III, IV, and V*, (NASA SP-129), U.S. Government Printing Office, Washington, D.C. 266 pp. 1967.

These two NASA publications contain a selection of the finest color space photographs of the Gemini flights listed. Informative captions are included with each photograph.

Photographs and imagery included were graciously furnished by the U.S. Geological Survey and the National Aeronautics and Space Administration.



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Others in preparation. Consult your NSTA publications list.

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