DOCUMENT RESUME

ED 115 497 SE 019 910

TITLE	NASA Facts, Why Survey from Space?
INSTITUTION	National Aeronautics and Space Administration, Washington, D.C. Educational Programs Div.
REPORT NO	NF-57/1-75
PUB DATE	75
NOTE	11p.
AVAILABLE FROM	NASA, FE/Educational Programs, Washington, D.C. 20546 (free to teachers); Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock Number 033-000-00619-5, $0.45)
EDRS PRICE	MF-$0.76 HC-$1.58 Plus Postage
DESCRIPTORS	*Geography; Instructional Materials; *Maps; *Photography; *Science Activities; Science Education; Secondary Education; Secondary School Science; *Space Sciences; Surveys
IDENTIFIERS	NASA; *National Aeronautics and Space Administration; SKYLAB

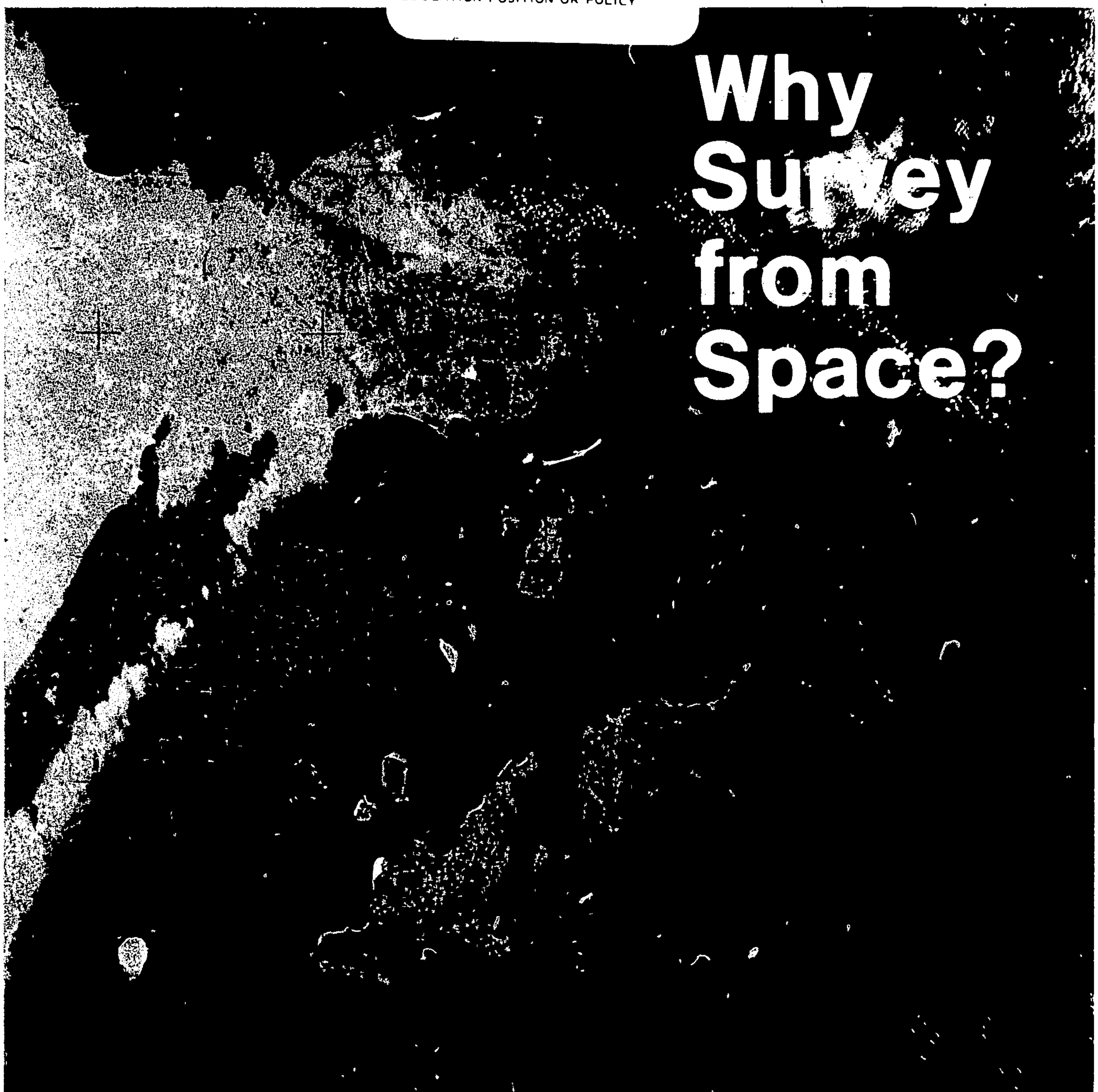
ABSTRACT

In this NASA publication, the technology behind the art of high-altitude surveying is explained in language understood by high school students. The principles behind ground-based surveys are first explained, then several diagrams are utilized in the explanation of photographic surveys. Additional information is provided concerning the use of stereo photography and the importance of lighting. Throughout the publication, examples of photographic surveying appear along with explanations of the uses of the photographs. Included in the work is an extensive bibliography and information for those interested in obtaining SKYLAB survey photographs. (CP)

NASA FACTS

AN EDUCATIONAL PUBLICATION OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NF-57/1-75



Why Survey from Space?

WHY GO UP THERE TO LOOK DOWN HERE ?

The objectives of this publication are to provide the reader with:

An understanding of the types of people who make and use surveys;

An understanding of what survey information is used for;

An understanding of some of the basic ground-based surveying techniques;

An appreciation of the importance of photographic surveys from aircraft or spacecraft;

An appreciation of the ways the readers can use *remotely sensed data* for their own surveys.

Throughout the text some examples of basic theory are included along with some open-ended questions. The reader's answers to these questions will measure how well the above objectives are achieved.

Who Wants Surveys?

Surveying is the process by which the size, shape, and locations of features on earth can be measured. Surveys are performed on the ground or by taking pictures from above the ground in aircraft and spacecraft, or both. The information we get from these surveys is used by many people in many ways.

The geologists use the survey to learn about the location of rock formations and the structures of mountains, minerologists need the information to locate mineral deposits for mining, petroleum geologists use the information to locate new oil-drilling operations, and hydrologists use the information to map water resources and natural flow patterns. Survey information is the basic requisite for making maps.

In the area of applied science, builders of highways, railroads, bridges, dams, canals, and airfields all need survey information.

Planners of local, state, and national land use activities also use survey information. They plan where to put new roads or widen existing roads, where to locate schools and recreation areas, where to locate reservoirs, and where to develop new industrial areas and residential areas.

What other uses can you think of for survey information? Think about the ways land is used, where cities are located, and population growth.

How Ground-Based Surveys Are Made

If the area is small, like the parking lot or athletic field at school, the survey can be made by directly measuring the important features with a measuring tape. If the size of the area is measured in kilometers rather than meters, the measuring tape technique becomes impractical. Some other method of surveying must be used that can be performed without walking all over the area.

Again, if the survey is only interested in the boundaries of the parking lot, the time required to complete it is small. But if all the parking spaces and light poles must be shown, the survey could take days. A detailed survey of the larger area would take much longer.

If the area to be surveyed is covered with jungle or is mountainous, the difficulty of seeing landmarks or moving around makes surveying difficult or even impossible.

How to Do Your Own Ground Survey

You can make a reasonably accurate survey of a nearby open space by using a homemade *alidade*, with a *plane table.* An alidade can be made by mounting a simple sighting device, such as a drinking straw on a straight edge, making sure that the line of sight is parallel to the straight edge.

The plane table is a small drafting board that must be set up in a horizontal attitude. A compass is also required to locate north (see Figure 1).

Set up the board at one landmark (A) in the area to be surveyed with a reference line pointing north. Mark a datum point (A′) on the paper to represent that landmark (Figure 2). Landmarks may include existing things such as corners of buildings, telephone poles, trees, etc, or special markers that you have placed. Sighting along the straw to the next landmark (B), draw a line with the straight edge through your datum point. Then measure the distance from A to B and mark that distance to scale along the line you have drawn. This gives you the location of B′.

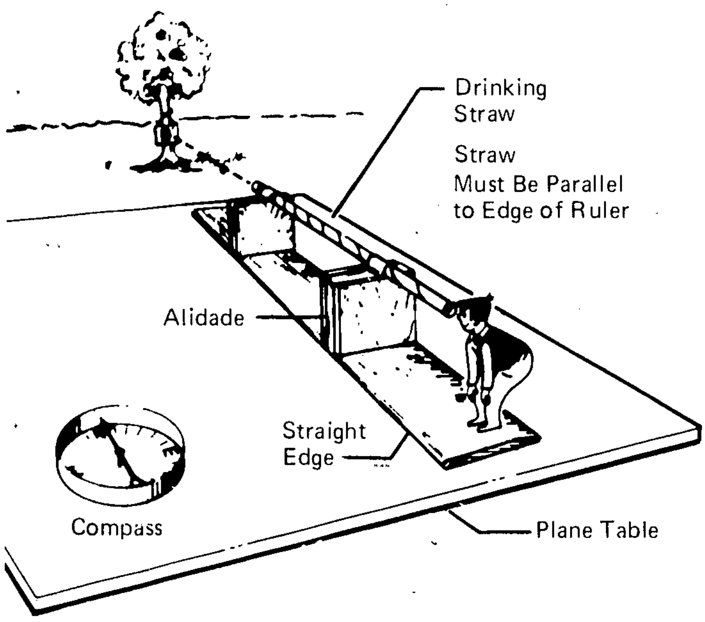


Figure 1 Alidade and Plane Table

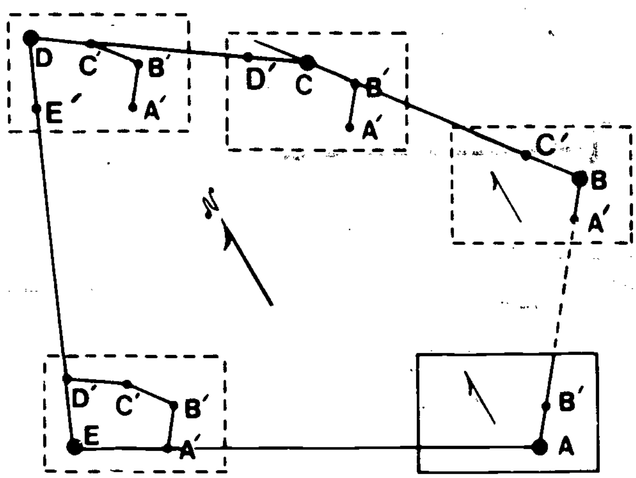


Figure 2 Surveying By Measuring Each Distance

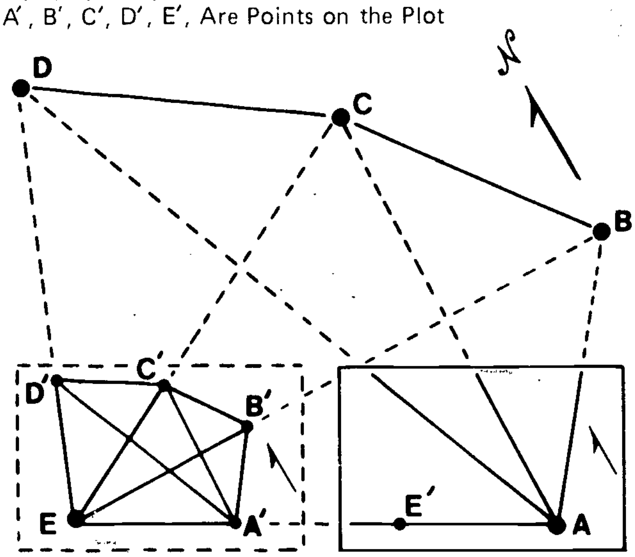


Figure 3 Surveying By Measuring Only One Distance

Now move your board above or alongside landmark B and make sure that your north-south line points in the right direction. Then draw a line from B′ in line with C, measure BC and mark the distance B′C′ to the same scale. From C follow around the landmarks, plotting directions and measuring distances until you return to A. *It is important that the north-south line be aimed correctly before plotting each direction.*

Another way to use the alidade is to set up the board at A and plot lines radiating from A′ and pointing to B and all other landmarks (Figure 3). Then measure the distance AE and mark off that distance to scale along the right line to establish a baseline A′E′. Move the board to point E, then plot lines from E′ that point at all other landmarks. The point where the line in the direction EC crosses the line AC is C′, and so on for all other points. Once again point the north-south line in the correct direction be... sighting on landmarks.

The two ground-based survey methods just described are the simplest and possibly the most basic methods. Other methods using more sophisticated instruments are also used by professional surveyors.

Photographic Survey

If the area to be surveyed contains buildings, trees, hills, or mountains that obstruct visibility of the landmarks, some other survey technique is needed.

An approach would be to fly over the area and take photographs. Modern cameras with good quality lenses can be used to map an area with much greater accuracy than ground-based surveys.

But how high do you fly? This depends on the size of the piece of ground to be surveyed, on the *focal length* of the camera, and the size of the image produced in the camera—the frame size.

The generalized equation is:

$$\frac{\text{Ground dimension}}{\text{Frame size}} = \frac{\text{Camera height}}{\text{Focal length}}$$

From this the height at which to fly can be derived:

$$\frac{\text{Ground dimension}}{\text{Frame size}} \times \text{Focal length} = \text{Camera height}$$

See Figure 4.

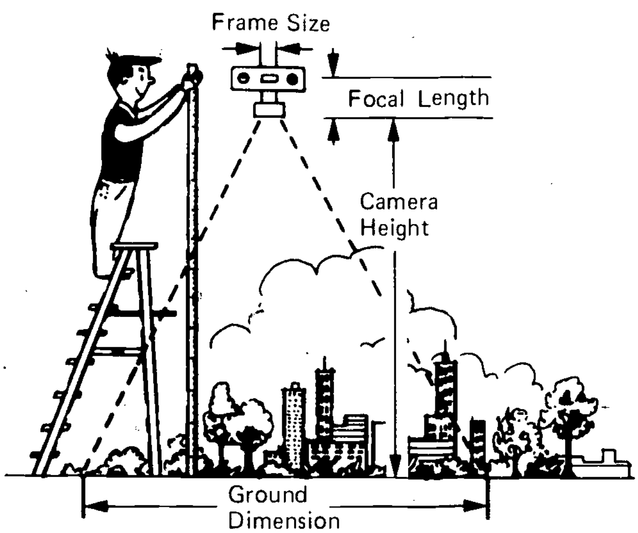


Figure 4 Camera Focal Length Versus Height

If the camera has a focal length of 75 millimeters and produces an image 22.5 millimeters square, the height necessary to photograph a 600-meter length becomes:

$$\frac{600 \text{ meters}}{22.5 \text{ millimeters}} \times 75 \text{ millimeters} = 2000 \text{ meters (2 kilometers)}$$

How high must you fly to photograph 6 kilometers, or 60 kilometers, with this camera?

If you don't know the focal length of your camera you can still find out how high to fly. Photograph a wall, making sure that the axis of the lens is at right angles to the wall. Measure the distance from the camera to the wall. It is important that the wall has enough recognizable features to help you to identify the area photographed in a print of the whole photograph. The calculation of camera height is now simple, see Figure 5.

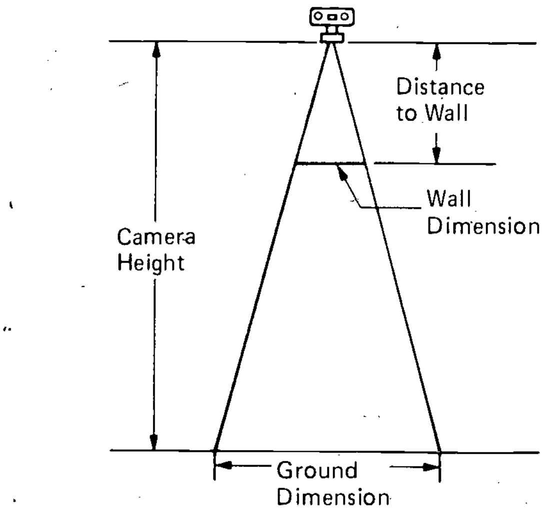


Figure 5 Picture Size Versus Distance

There is, however, a problem related to high-altitude photography of the earth. That is, you lose detail as you move farther away from the object to be photographed.

There is a limit to the size of the image that can be recorded on film, because of the size of *grains* in the *light-sensitive emulsion* on the film. The limiting size is called the *resolution* of the film. Resolution is measured by counting the number of pairs of black and white lines that can be seen on a millimeter of film. The ability to resolve the lines depends on the contrast. The more *line-pairs per millimeter*, the higher is the resolution.

If the film in the camera we used above has a resolution of 50 line-pairs per millimeter, it could record 50 x 22.5 = 1125 line-pairs across the film. The smallest feature that could be *resolved* in a photograph taken from 2 kilometers high would be:

$$\frac{600 \text{ meters}}{1125 \text{ lines}} = 0.5333 \text{ meters (53.33 centimeters)}$$

That means you could detect a fat man from 2 kilometers. What would be the smallest resolvable objects in the photographs of the 6-kilometer and 60 kilometer areas?

To identify a feature in a scene it is necessary to see a number of these smallest resolvable elements. The optical quality of the camera also affects resolution.

Another problem related to photographic resolution is motion. If the camera is moving, as in an aircraft or spacecraft the picture may be blurred. One way to get around this is to use a very fast film that allows exposures so short that the motion is not apparent on the photograph. Unfortunately most very high-speed films have large grain sizes and relatively poor resolution, and high resolution films usually have slow film speeds. Film manufacturers can supply the necessary information. A compromise is necessary between allowable loss in resolution due to motion and film. Aircraft and spacecraft cameras often have built-in mechanisms to compensate for this motion.

Also it is important that the axis of the camera be at right angles to the ground. If not, the picture will be distorted with loss of accuracy of dimensions, see Figure 6. Correction of this can be made in the analysis of the picture.

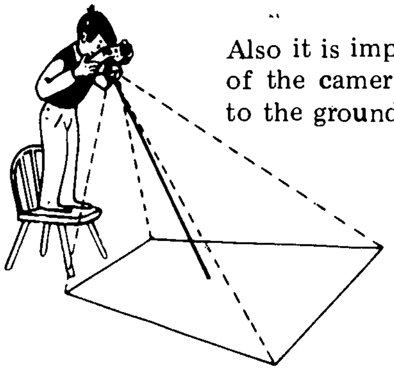


Figure 6 Distortion of Picture

Stereo Photographs

Photographic surveys give you something else in addition to accurate pictures. That is, *stereoscopic* pictures of the terrain can be made. These can be used for map making. We are all familiar with the three-dimensional view we get because our two eyes are spaced about 60 millimeters apart. This stereo effect can be increased by spacing the eyes farther apart. This is done when using prismatic binoculars where the spacing of the objective lenses is increased to about 15 centimeters. If two photographs of a scene are taken from two separate points, a stereo effect can be obtained. The two pictures must be of the same scale and must overlap each other so that each point in the scene is included in the two pictures—a *stereo pair*. The pictures are mounted side by side with the scenes about 60-millimeters apart. A stereo viewer consisting of two magnifying lenses mounted on a frame, as shown in Figure 7, is set up over the picture. The spacing of the pictures must match the spacing of the lenses. As you will discover if you experiment with stereo pairs, the alignment of the photographs is very important.

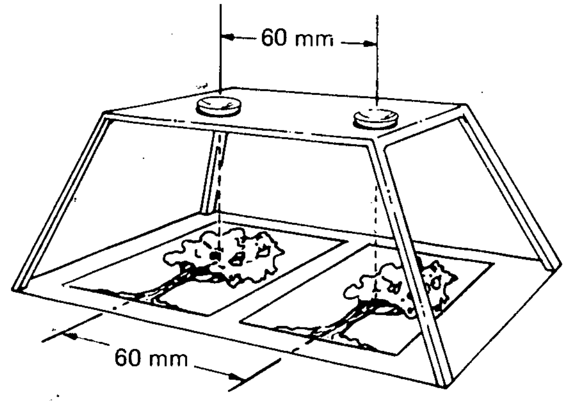


Figure 7 Stereo Viewer

Be sure that the left eye picture is under the left eye lens and the right eye picture under the right eye lens. If not the stereo effect will be reversed and the clouds will appear farther away from you than the ground.

Incidentally most of the photographs obtained with the Skylab cameras were taken at the right spacing for making stereo pairs. You can order them from the Earth Resources Observation System (EROS) Data Center (see page 7).

The pair of pictures printed below, Figure 8, were taken from Skylab over Colorado. The pictures show snow-covered mountains with the snow line at about 11,300 feet. The valleys are around 9000 feet above sea level. About 20,000 feet above this scene is a layer of cirrus clouds. In the lower right corner the cloud layer is so faint that it can barely be seen in each print. It is quite clearly detected when the stereo viewer is used.

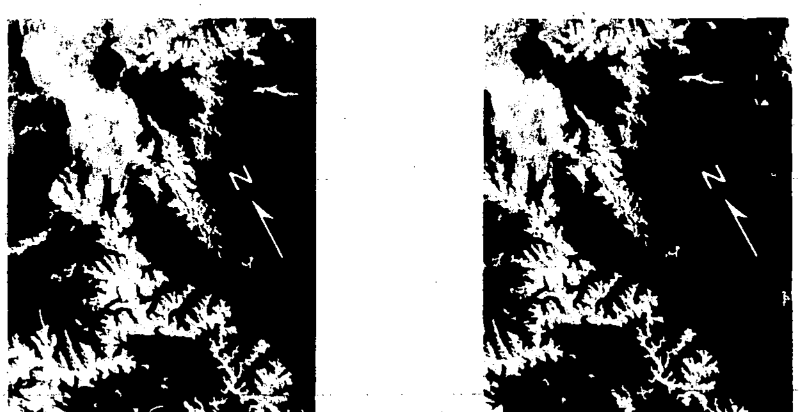


Figure 8 Stereo Pair, Leadville, Colorado

Stereo photographs are used in making maps. A scanner is used that can plot contour lines traced from the photographs.

Two projectors, located above a table, project a pair of stereo photographs down to the table. The operator has a smaller adjustable table located above the main table. He adjusts the height of the smaller table so that the projected pictures give the impression that a spot marked on its surface is just resting on the surface of the ground in the photographs. The spot is moved around the projected photographs following the points where it just rests on the surface of the ground in the scene. A pen linked to the small table draws tracks, which are the *contour lines* of the terrain. An operator using one of these scanners at the Geological Survey Office in Denver, Colorado is shown in Figure 9.

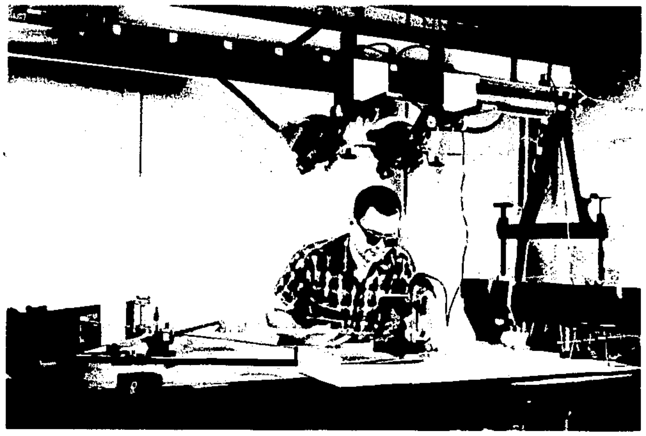


Figure 9 Stereo Map Plotter in Use

An interesting class field trip would be to visit a U.S. Geological Survey office, if there is one in your area.

Using such an instrument and Skylab photographs, a group of investigators revised maps of several locations in Latin America. The maps of the area surrounding the city of Santa Cruz in Bolivia were revised from one stereo pair of pictures. The original map, printed in 1972, was compiled from photographs taken between 1950 and 1969 and took hundreds of man-hours to prepare. The 1974 revision was made from two photographs taken in June 1973, and required only 24 man-hours to prepare.

The Effect Of Lighting in Photographic Surveys

It is obviously important that the scenes you are photographing be illuminated. Not only must there be light, but it must be of the right type and must shine from the right direction. You know that blue objects look dark when illuminated by red light and that red objects look dark when illuminated by blue light. The color of daylight does not change quite as much as that, but there are mornings and evenings when the sunlight has a distinct orange color that could affect the appearance of natural features photographed at those times. These color effects are detectable on black and white film as well as color film.

Of greater importance is the angle at which sunlight shines on the earth. As the earth rotates under the sun, the sun first appears just above the horizon in the east, then high in the sky at midday, finally disappearing over the western horizon. The lower the sun is in the sky, or the lower the *sun angle*, the longer are the shadows cast by features on the ground. When the sun is overhead almost no shadow is cast. The two pictures below (Figure 10) are of Las Vegas, Nevada, with very high and medium sun angles. How do you tell which is the higher sun angle?

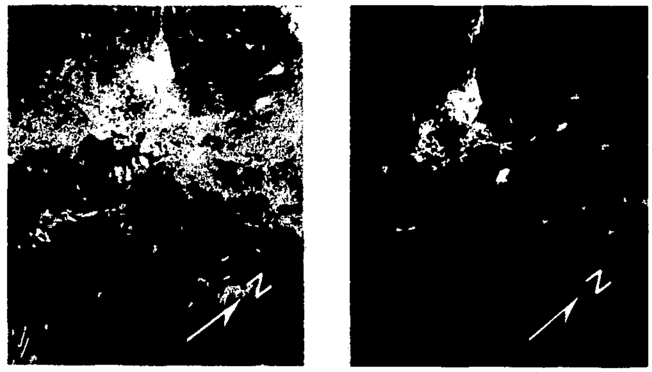


Figure 10 High and Low Sun Angle
Las Vegas, Nevada

For a photographic survey moderate sun angles are necessary to cast the shadows by which the irregularities of the terrain are portrayed. Too low a sun angle will produce long shadows from tall features that will obliterate all signs of adjacent smaller features.

The need to take survey photographs within a specific sun angle range, for example 10° to 30°, restricts the photography to specific times of day.

What times of the day would be appropriate to take survey photographs with the 10° to 30° sun angle limitation mentioned above?

The most direct way to answer that question is to record the angle of the sun above the horizon at each hour of the day for several days of the year—say once a month or once a week. To do this, mount a protractor on the edge of a board and pivot a pointer at the center of the protractor. Insert two thin nails or pins on the centerline of the pointer and a piece of card at one end as shown in Figure 11. Set up the device on a level surface in the sunlight and rotate the pointer so that both pins cast a single shadow on the card. The angle of the pointer is the sun angle for that time. DO NOT LOOK AT THE SUN! THIS CAN BE DAMAGING TO THE EYES!

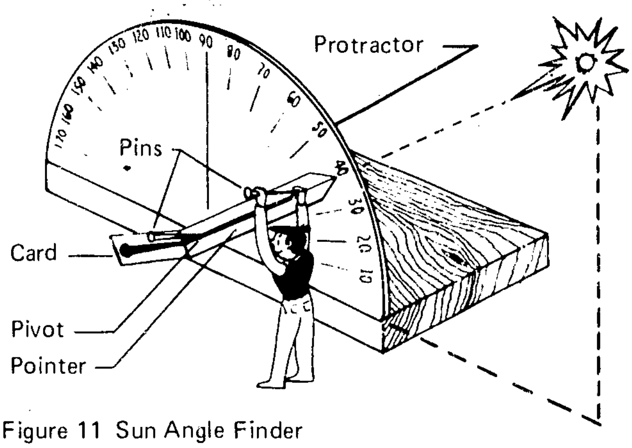


Figure 11 Sun Angle Finder

Those who are analytically inclined can answer the question by looking at the daily and annual movements of earth. As you know, earth travels around the sun once in a year, and rotates about its own axis once in a day. The axis of earth is inclined about 66 2/3° relative to the *ecliptic*—the plane containing the earth's orbit around the sun (Figure 12). Twice a year the axis of earth is perpendicular to the earth/sun line, that is—the earth's north and south poles are the same distance from the sun and the equator is in line with the sun.

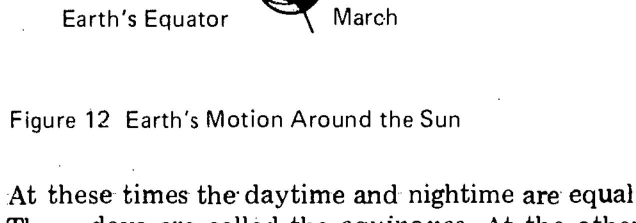


Figure 12 Earth's Motion Around the Sun

At these times the daytime and nightime are equal. These days are called the *equinoxes*. At the other two points shown in Figure 12 the earth's north pole is inclined toward or away from the sun, and the equator is inclined relative to the earth/sun line.

To an observer on the equator of earth at the equinoxes the sun will be seen to rise vertically upward from the eastern horizon, pass directly overhead at noon, and descend vertically to the western horizon at sunset. On these days (March 21 and September 21) at the equator, the sun angle changes by 15 degrees an hour (earth's rotation about its axis).

From the above discussion and Figure 13, calculation of the times of day appropriate for photography at the equinoxes at the equator should be straightforward.

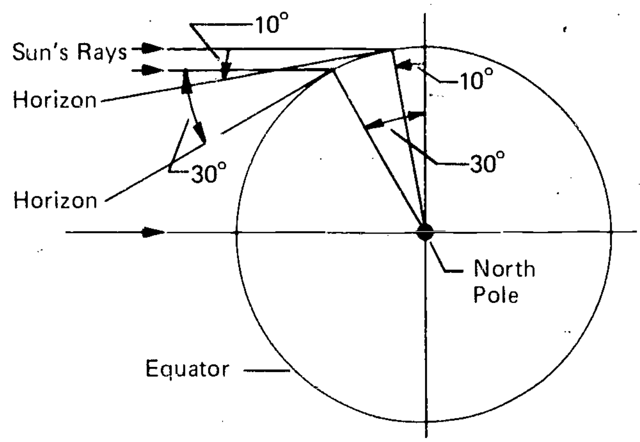


Figure 13 Earth Rotation and Sun Angle

The location of the scene to be photographed has a large effect on photo survey opportunities. A winter survey of Anchorage, Alaska (north latitude 61° 10′) would be impractical if the 10° minimum sun angle applies. Why is this so? Figure 14 will help to answer this. The answer is in the angle X.

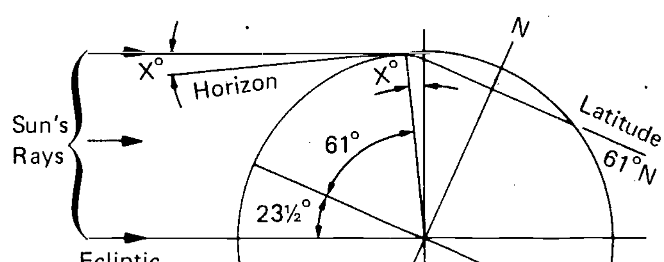


Figure 14 Winter Sun Angle in Alaska (Noon, December 21)

8

The Importance of Timing in Surveys

An important aspect of surveying, whether by photography or any other method is how much time you can afford to spend on the survey or at what time of year the survey should be made. Let us consider a few special cases. If you were required to monitor the spread of water at St. Louis, Missouri, in the March 1973 flood, it would be ridiculous to use a technique that needed three weeks to make one survey of the area. By the time the first set of data is complete, the flood waters will have risen to a maximum and receded. The survey would be meaningless.

Another survey program could be planned to record the growth of a city. Two surveys a year might be adequate but each survey should be completed in a short time, perhaps a week.

A hydrologist measuring the amount of water that could flow from snow fields in the mountains might want to make weekly surveys of the spread and recession of the snow from the first snowfall through early summer.

At what time of year would a midwestern wheat farmer make an aerial survey of his land to evaluate his wheat crop? How often would a map maker survey the mountains to plot the directions of ridges and valleys and the locations of peaks? Is there a time of year that is best suited to getting this information?

From these examples you will see that a surveyer must identify what is the important feature in his survey, and must appreciate the rate at which it might change and the effect of the weather so that he can select the most suitable survey technique.

Summary

In summary the following considerations should be evident:

1) That ground-based survey can provide extremely detailed information, but it can be extremely time consuming.

2) That a photographic survey from aircraft or spacecraft can provide information about a scene much quicker and, often, more accurately than a ground survey.

3) That all areas are accessible for photographic survey from aircraft or spacecraft.

4) That large areas can be photographed in a single exposure from high altitudes.

There are certain disadvantages or limitations related to survey from altitude. These include:

1) Loss of detail unless elaborate cameras and techniques are developed.

2) If sophisticated cameras are to be developed, the initial cost may be high. This cost must be balanced against the cost of obtaining the same information in an acceptable time by other methods.

NASA Photographs Can Be Used for Surveys

You can realize the values of photographic survey from spacecraft by studying photographs of earth taken by NASA's Skylab astronauts or by NASA's Earth Resources Technology Satellite (ERTS). These can be obtained from EROS Data Center.

The EROS Data Center in Sioux Falls, South Dakota, is operated by the Topographic Division of the Geological Survey for the Earth Resources Observation Systems Program of the Department of the Interior. This center provides access to satellite earth resources imagery, aerial photography, and NASA aircraft data for the general public, United States government agencies, and foreign governments.

Data can be obtained from the EROS Data Center by phone, in person, or by letter.

1) Telephone
7:00 a.m. to 7:00 p.m.
(605) 339-2270

2) Visit
7:45 a.m. to 4:30 p.m.
EROS Data Center
10th and Dakota Avenue
Sioux Falls, South Dakota

3) Write to:
EROS Data Center
Sioux Falls, South Dakota 57198

More information on how to get photographs can be obtained in: "The EROS Data Center," published by United States Department of Interior Geological Survey, EROS Data Center, Sioux Falls, South Dakota 57198, 1972.

When you get the photographs you can actually use them in a number of ways:

Compare them with maps of the area and note changes that have developed. The spread of housing developments, new roads, dams, and changes in river flow are the types of changes you should be able to see. For example, the illustration on this page was developed in the Santa Cruz, Bolivia survey mentioned on page 5. The photograph shows the course of the Rio Piray as photographed from Skylab in June 1973. The plot superimposed is taken from the 1972 1:50,000 scale map.

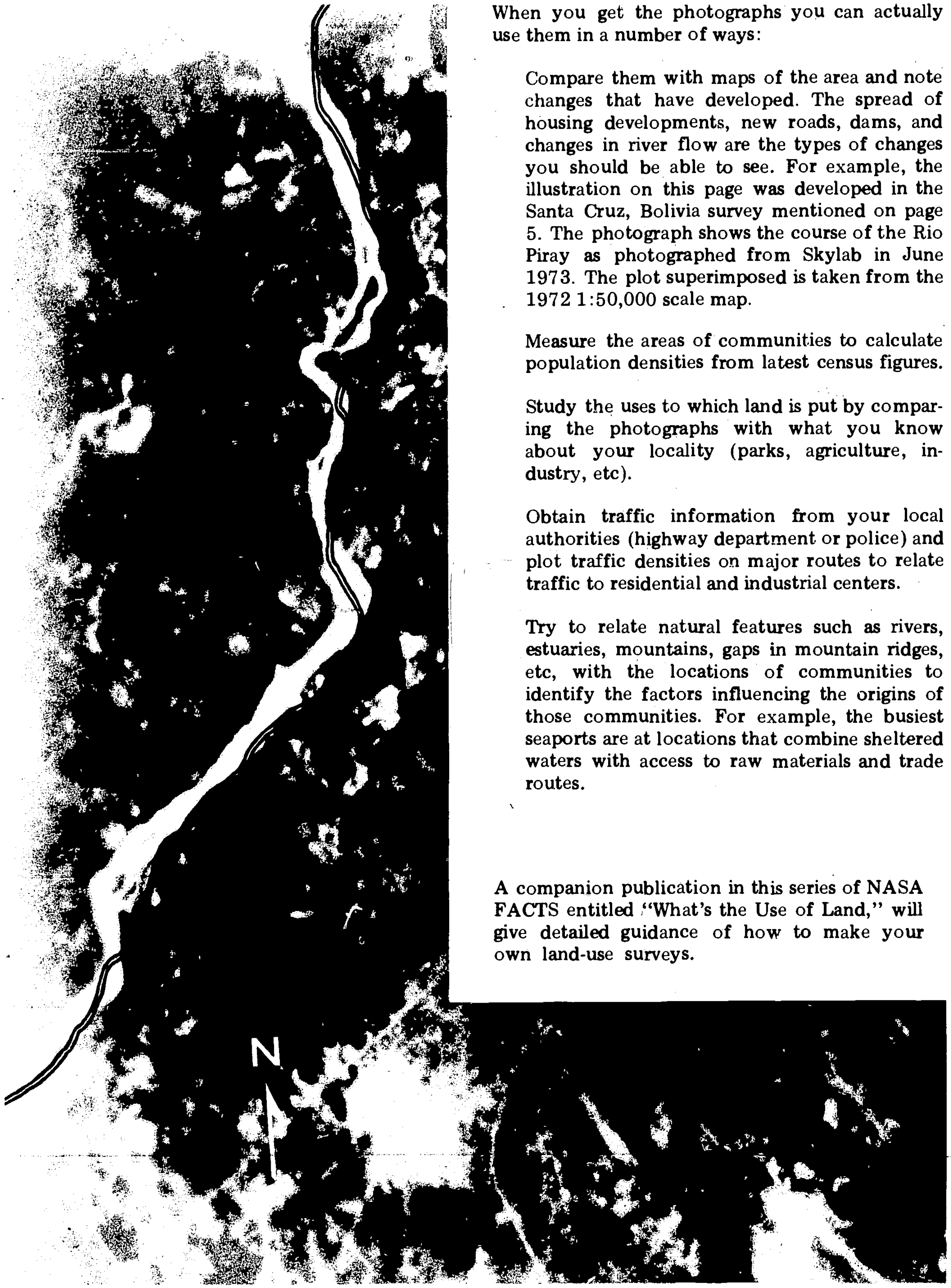
Measure the areas of communities to calculate population densities from latest census figures.

Study the uses to which land is put by comparing the photographs with what you know about your locality (parks, agriculture, industry, etc).

Obtain traffic information from your local authorities (highway department or police) and plot traffic densities on major routes to relate traffic to residential and industrial centers.

Try to relate natural features such as rivers, estuaries, mountains, gaps in mountain ridges, etc, with the locations of communities to identify the factors influencing the origins of those communities. For example, the busiest seaports are at locations that combine sheltered waters with access to raw materials and trade routes.

A companion publication in this series of NASA FACTS entitled "What's the Use of Land," will give detailed guidance of how to make your own land-use surveys.



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Acknowledgments

Suggestions from the National Science Teachers Association and the National Council for the Social Studies have been extremely helpful in the preparation of this document. Special appreciation is expressed for the support provided by:

Dr. James R. Wailes, Professor of Science Education, School of Education, University of Colorado, Boulder, Colorado

Dr. Lee R. Summerlin, Associate Professor of Chemistry and Science Education, University of Alabama, Birmingham, Alabama

Dr. Wendell F. McBurney, Assistant Dean, Office of Sponsored Programs, Indiana University—Purdue University at Indianapolis, Indiana

Mr. Richard L. Steiner, Associate Professor of Education, Lewis & Clark College, Portland, Oregon

Mr. Anthony J. Petrillo, Director of Secondary School Curricula, Jefferson County Schools, Lakewood, Colorado

Mr. Roger Howard, Planetarium Director, Boulder Valley Schools, Boulder, Colorado

Mr. Manly Tory, Science Department, Bloom Township High School, Chicago Heights, Illinois

Mr. Harold Pratt, Science Coordinator for Jefferson County Schools, Lakewood, Colorado

Dr. Gerrit L. Verschuur, Professor of Astro-Geophysics, University of Colorado, Boulder, Colorado

Ms. Marilee Bradbury, Mr. Dean Larson, Mr. Alan Swanson; Jefferson County Schools, Colorado

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☆ U.S. GOVERNMENT PRINTING OFFICE : 1975 O—579—720