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Satellite Photos Can Aid Navigation on Aerial Photo Missions

Landsat images provide an alternative when other navigation materials are not adequate.

Abstract: *Landsat photos can be an aid when maps are too old, lack proper information, are the wrong scale, or are not available. They also can be used to resolve problems when aerial photos are used as maps. It is important to select the best available spectral band and Landsat photographic products. Methods for scaling the satellite image and producing black-and-white photo prints are described.*

Introduction

Satellite photos have proven valuable as navigation aids on aerial photo missions by saving time and reducing re-flights because of navigational problems. Accurate navigation is important to the success of aerial photo missions. The photo pilot and aerial photographer navigate along preselected flight lines by relating visible ground features to information on existing maps or aerial photos marked with flight lines. The accuracy of their navigation depends on the amount of useful information available on the flight maps or photos. If maps or aerial photos are not available, or if they lack adequate information, current satellite imagery (Landsat photos) can be enlarged for use as navigational aids. This technique has been tested and proven successful on operational aerial photography missions.

Photo Mission Planning

Careful mission planning can be ineffective if good navigational aids are not available to a photo crew.

Usually one of the first problems encountered in planning a photo mission is the availability of adequate maps or photos. It is most important that an observer flying in an airplane be able to identify features on the ground using these aids (maps or photos). Some methods used and problems encountered when using maps and aerial photos are discussed below.

Map Coverage

Adequate maps for aerial photography may not be available because

- Map coverage does not exist for the photo site;
- Only partial coverage is available; or
- If maps are available, they may be of drastically different scales, making it difficult to assemble them for block coverage and making them unusable.

Even when adequate map coverage is available for mission planning, it may not be adequate for aerial navigation. Maps may be outdated and lack current ground features. The ground features referenced in detailed map information may not be visible or recognizable from high altitude and may actually clutter the map. Ground features which are especially useful for in-flight orientation (e.g., vegetation types, land-use patterns, and physiographic features) may not appear on the map.

Although a particular map may not be usable for in-flight navigation, it may be useful for mission planning. For example, maps provide necessary information such as geographic features, measurement criteria (linear scale), and ground elevation needed to plan the mission. With the infor-

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mation available on a map, flying height can be determined and flight lines can be accurately plotted to provide aerial photo coverage at a given scale with proper overlap and sidelap between pictures.

AERIAL PHOTO COVERAGE

Existing aerial photo coverage also can be used for mission planning and navigational aids. The greatest advantage of aerial photos is that they provide a pictorial record of identifiable ground features. If small scale (1:50,000 to 1:120,000) photos are available, they can be enlarged to a scale more compatible to the flying height of the mission being planned. Another approach is to use existing 9 by 9 inch contact prints and assemble them in either strips or a mosaic.

However, plans to use existing aerial photographs also may not be practical. It may be difficult to locate sources of existing aerial photography, photo coverage may not be complete, the source may not want to release the photography, or duplicated photo products may be too expensive to use (e.g., original film may be color or color infrared transparencies).

Although maps and existing aerial photos should be considered first when looking for navigational aids, if there are problems in finding adequate coverage, the use of satellite photos should be considered.

SATELLITE PHOTO COVERAGE

A photograph made from Landsat Multispectral Scanner (MSS) data is a pictorial record of ground features that can be recognized from the air. These satellite images are readily available, are usually not more than one year old, and, in terms of current land-use conditions, are relatively up-to-date. Satellite images also reflect more closely what is on the ground than does a map (Figures 1 and 2).

Satellite photos also are useful where high altitude navigation (15,000 to 30,000 feet) poses a problem because of the diversified and changing land-use patterns. Ground features that appear on

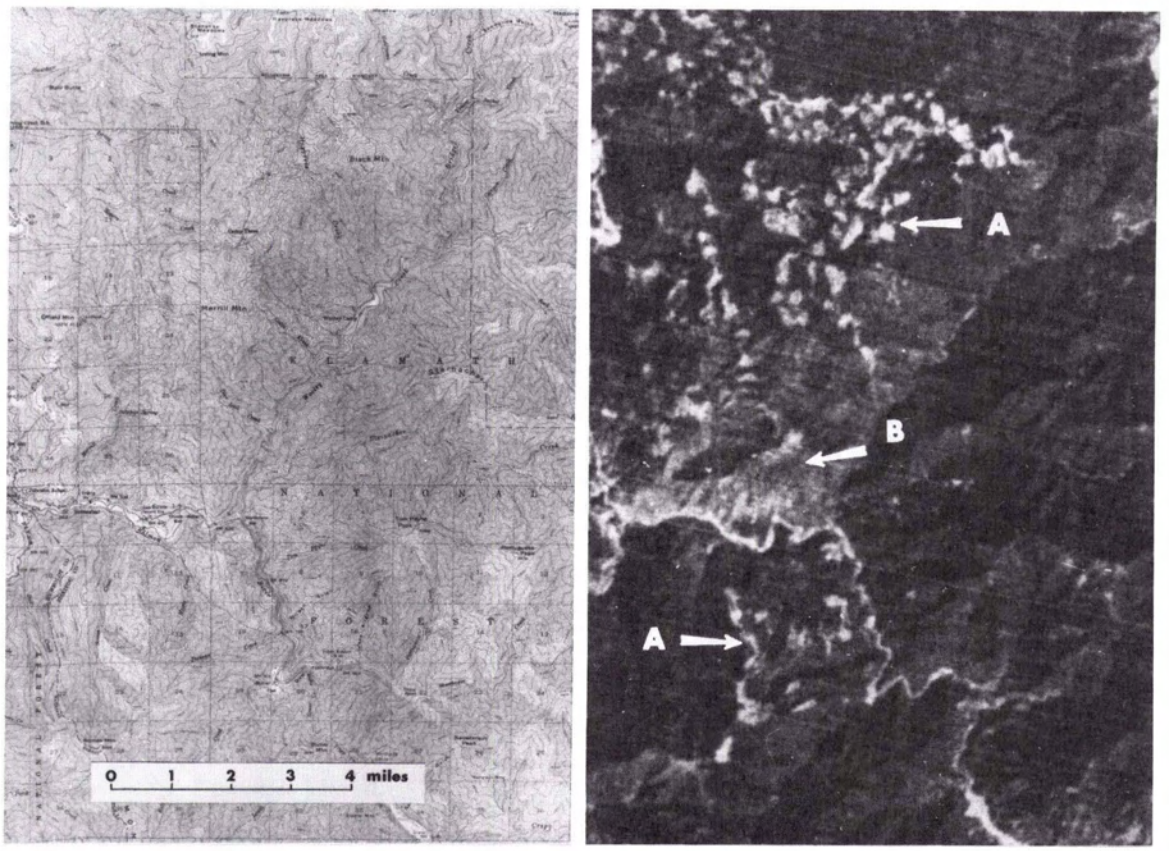

FIG. 1. A portion of a 15-minute quadrangle map (left) illustrates a timbered mountain area in the Klamath National Forest in northern California. A Landsat MSS band 5 image (right) was enlarged to the original map scale (1:62,500) for aerial navigation. Clearcut logging units are shown at (A) and a recent burn—forest fire area is visable at (B).

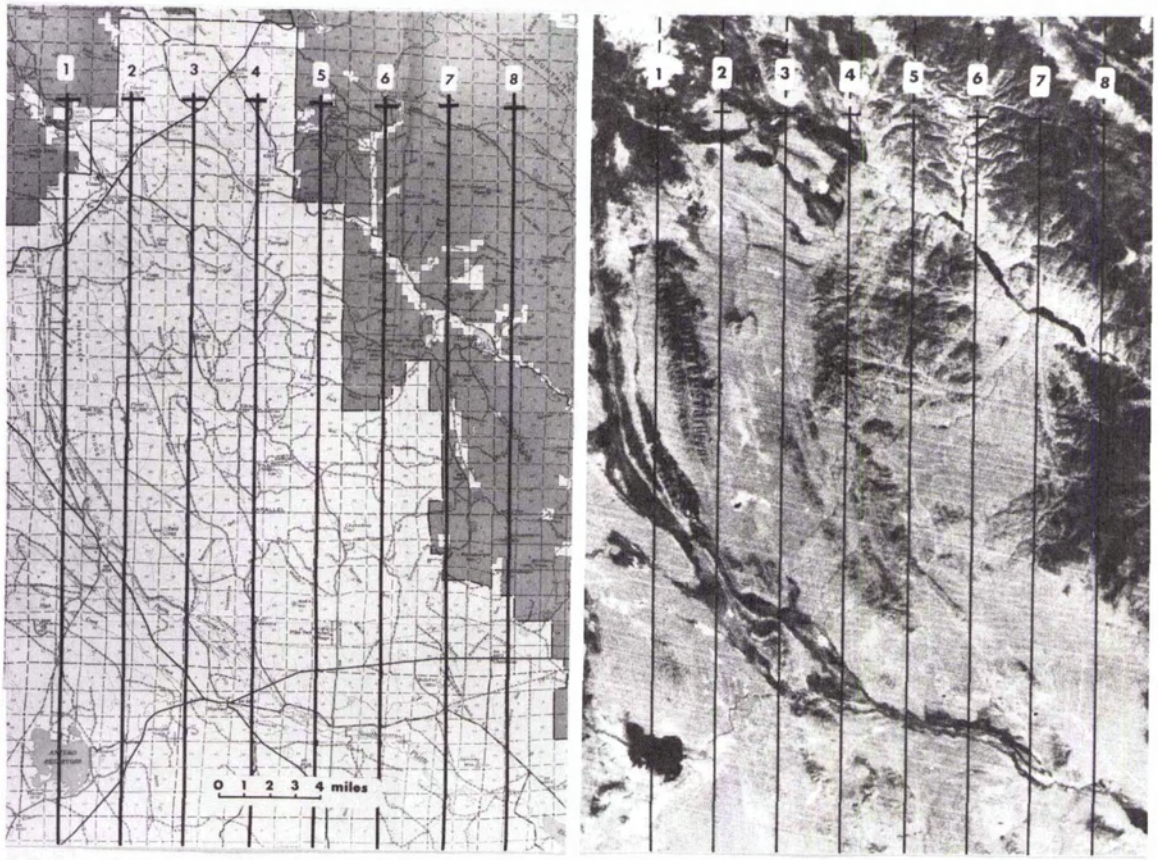

FIG. 2. A U.S. Forest Service map (left) at an original scale of ½ inch = 1 mile (1:126,720) shows a portion of the South Park basin located west of Pikes Peak and Colorado Springs, Colorado. The dirt road systems and small streams (shown on map) were not recognizable from high altitude. A Landsat MSS band 5 image (right) was enlarged to the map scale for use in navigation. Flight lines were plotted on the map and then transferred to the satellite photo enlargement.

conventional maps (road systems, streams, small towns, etc.) are obscured or lost due to the complex patterns of bare fields, agricultural crops, and timber stands. Satellite photos can show the current land-use patterns and are a definite advantage for navigation.

LANDSAT IMAGERY

IMAGERY

MSS Bands 5 and 7 were found to be the most useful for navigational aids, with band 5 superior to band 7 in most cases. Band 5 is best for showing topographic, vegetative, and cultural features. Band 7 is best for showing geologic features, water (lake and rivers), and features influenced by water (wetlands, irrigated lands). When selecting the band that will provide the greatest amount of useful information, consider the photo site in terms of the most predominant ground features identifiable from an airplane.

Landsat images are available in two film formats—70 mm (2.2 inch image size) or 9 by 9 inch (7.2 inch image size). The 70-mm format is at a scale of 1:3,369,000; 1 inch on the film represents approximately 53 miles on the ground. The 9 by 9 inch format is at a scale of 1:1,000,000; 1 inch on the film represents approximately 16 miles on the ground. The two standard formats are available in black-and-white negatives or positive transparencies.

AVAILABILITY

Landsat products are available to government organizations, universities, industries, and private individuals from the Earth Resources Observation Systems (EROS) Program, administered by the Geological Survey of the U.S. Department of the Interior. To place an order or request information, contact

User Services
EROS Data Center
Sioux Falls, South Dakota 57198
Phone: (605) 594-6511
FTS: 784-7151

For agencies of the U.S. Department of Agriculture, Landsat photo products are available from the Agricultural Stabilization and Conservation Service (ASCS). To place an order or request information, contact

User Services
Aerial Photography Field Office
U.S.D.A.—A.S.C.S.
2222 West 2300 South
P.O. Box 30010
Salt Lake City, Utah 84130
Phone: (801) 524-5856
FTS: 588-5856

Landsat images are cataloged and indexed by row, path, and scene numbers, and characterized by quality of image. If the user does not know this information, he can obtain a list of existing coverage by specifying the latitude and longitude of the four corners of the area of interest. The user may also specify the time of the year that the imagery was acquired. If the area of interest is quite small, center coordinates instead of corner coordinates may be designated. An alternative method would be to delineate the area of interest on a map and send the map to the appropriate User Service group, requesting information for available images.

Methods

Final products desired

Decisions about whether to order a negative or a positive transparency, and whether the choice of format size should be 9 by 9 inches or 70 mm, depend on the amount of enlargement required in the final product. A 70-mm format usually requires too much enlargement; therefore, a 9 by 9-inch format generally is preferred. If sufficient enlargement to the final product can be accomplished in one step, a negative image should be ordered. If, however, the required enlargement cannot be made in one step, a positive transparency should be ordered. In this event, the specific area of interest is enlarged from the positive image to make a negative. This enlarged negative is then enlarged to the final photo product. The approach used to produce the final product will depend on the capability of the photo enlarger.

Photo scaling

There are two methods to enlarge the Landsat image to the desired scale. One method is to select an available map base and place the map in a printing frame (easel) under the enlarger. With the Landsat image (negative or positive) in the enlarger, adjust the height and focus until features on the map and satellite image are superimposed. Several base maps have been used for scaling Landsat photos: USGS 1:250,000 scale maps; Forest Service ½ inch = 1 mile (1:126,720 scale) maps; and USGS 15 minute quadrangle (1:62,500 scale) maps. The amount of enlargement required from a 1:1,000,000 scale satellite image to these map scales is 4×, 8×, and 16×, respectively.

A second method of scaling the Landsat image is to select a convenient scale to be used for plotting flight lines (final navigation aid) and enlarge the Landsat image to this scale. Begin by measuring distances on a map using land features that can be recognized on the satellite image. Then, using simple ratios, calculate the distance required to produce a Landsat enlargement at the selected scale. Adjust the enlarging equipment until the projected image on the printing easel meets the calculated measurements.

Photo materials

Photo products from satellite imagery can be produced in a photo lab (darkroom) using standard enlarging and processing equipment. Myhre[1] described a method for producing high-quality black-and-white negatives from satellite positive transparencies. Changes in film density and contrast of negatives owing to reciprocity[2] effects are controlled by calculating adjustments in exposure and development. Kodak Ektapan Film (Type 4162)[3] was used to record the negative image, and then was processed in Kodak Microdol-X Developer.

Enlarging the negative image to the final photo print requires that an enlarger and processing trays large enough to accommodate the size of photo paper be used. Enlargements are made on a variable contrast photo paper with contrast controlled by filters in the enlarger system. Contrast control is critical to bringing out the key ground features. Kodak Polycontrast Rapid R C paper has the necessary speed to handle exposures required by 10× to 20× magnifications. R C paper is a printing material with a resin coated back that reduces processing and drying times. The overall processing time (including washing) for R C paper is approximately 8 minutes, where regular paper requires 30 to 40 minutes. A non-glossy paper

[1] Myhre, R. J., 1973. *Producing high quality negatives from ERTS black- and white transparencies.* USDA Forest Service Research Note PWS-287, 6 p. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

[2] Reciprocity Law—A constant density is obtained on a photographic material if the product of the intensity of light and the time for which it acts is constant. Reciprocity failure occurs when extremely short or extremely long exposures are used.

[3] The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

surface such as "N" is required for annotating the print with flight line information.

At least two copies of each satellite photo should be made—one copy for the aerial photographer's use and a copy for the pilot. A third copy may be needed later as a photo index sheet to plot the aerial photo coverage.

If photo lab facilities are not available, care must be taken in requesting commercial photo work. Probably the best approach is to place the Landsat image in a transparent sleeve (protective envelope) and annotate on the sleeve the area to be enlarged and the image corners in case the film should shift position. Specify the amount of enlargement needed for a given area needed to get the final product at the scale required.

MISSION PLANNING

The initial mission planning should be done with a map at the same scale as the Landsat photo. The locations of the flight lines on the map with proper spacing between lines for the desired side lap, should then be plotted (Figure 2). Next, determine the mean ground elevation along each flight line, and calculate the flying height required to obtain a given photo scale. Once the mission parameters have been determined, transfer the flight lines to the copies of the Landsat prints.

If the only available map is at a different scale, flight lines can be plotted on the map and transferred to the satellite photo enlargement using ground features. If this is not practical or possible, flight lines can be plotted directly on the photo enlargement using scale information (ratios). The only mission parameter that requires map information is the mean ground elevation for the flight lines.

DISCUSSION

Satellite imagery does not replace conventional navigational aids such as maps and aerial photos. It is an alternative method that can be used when other navigation materials are not adequate for the purpose. Landsat photos have proven to be an effective operational tool on photo missions.

A word of caution is stressed in selecting the date of Landsat imagery to be used in areas of the country where widespread vegetation changes occur. Hardwood forest defoliation and agricultural land before growth occurs are examples where problems could arise if the Landsat photo is from a different season than the actual flight. It is important to select a satellite image that represents the time frame of the anticipated aerial photo mission. The Landsat scene could be for the same general time period, but one year earlier. One problem encountered with one-year-old imagery is that croplands could have been rotated. In this case, the photo crew must utilize pattern and shape relationships instead of tones and textures.

Satellite photos are most effective for medium to high altitude (10,000 feet above ground and up) photo missions. The higher the altitude, the more advantageous a Landsat photo becomes over a map for in-flight navigation. For lower flight altitudes, a Landsat photo would have to be enlarged greatly and fine detail would be lost, because of the resolution limits of the MSS.

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