PROCEDURES FOR PLANNING REMOTE SENSING MISSIONS

by L. E. Link, Jr.

Mobility and Environmental Systems Laboratory

PART I: PHOTOGRAPHIC MISSIONS*

Introduction

Remote sensing began in 1840 when Gaspard Felix Tournachan took a photograph of an area near Paris from a balloon. Since then aerial photography and recently a variety of more exotic sensors have been used to acquire a staggering amount of terrain data for application to engineering and environmental problems. In spite of the broad application of remote sensing techniques, the methods employed by the user community to plan and execute remote sensing missions remain empirical and at times mainly subjective. As our need increases for more detailed and specific data over larger and larger areas, remote sensing will be more and more in demand as a data-acquisition tool. The increased detail in the data needed will require added sophistication in the methods used to successfully employ remote sensing to acquire these data.

Under sponsorship of the Military Construction Directorate, Office of the Chief of Engineers, the Waterways Experiment Station (WES) has developed mission planning procedures that provide for the first time rigorous and quantitative means to examine the effects of the major variables that influence the information content of remote sensor imagery. As such, they make possible the objective selection of a sensor system and mission profile (sensor altitude, time of day, atmospheric conditions, etc.) to enhance the success of a data-acquisition program.

Approach

In some cases imagery obtained with remote sensors constitutes the only practical source of information for mapping the geographic distributions of engineering and environmental factors over large areas. The synoptic view and advantage of rapid repetitive coverage can also be extremely valuable for monitoring dynamic phenomena such as suspended material plumes in water bodies.

Remote sensing techniques can by no means supply all of the Corps of Engineers' engineering and environmental data needs; however, properly used they can provide an extremely cost-effective means for acquiring a wide variety of pertinent information. The words "can provide" must be emphasized in that executing a successful remote sensor data-acquisition program is not a simple task.

Successful application of remote sensing to data acquisition requires that the following six steps be implemented:

- Problem specification.
- Acquisition of ground control data.
- Remote sensor data acquisition.
- Data manipulation.
- Information extraction.
- Information presentation.

Problem specification consists of defining the problem to be solved, specifying the types of data that are necessary to solve it, and determining the applicability of remote sensing techniques for supplying any or all of the necessary data.

* This article, the first in a series intended to introduce newly developed mission planning techniques to potential users, concerns the procedures developed to help plan photographic remote sensing missions. Future articles will concern mission planning for thermal infrared sensor systems, mission planning for microwave sensor systems, and the economics of remote sensing. References 1 to 5 give detailed documentation of the material presented herein and are available upon request.
Acquisition of ground control data consists of obtaining information necessary for accurate interpretation of remotely sensed data and possible specification of the remote sensing techniques best suited for the problem.

Remote sensor data acquisition consists of the actual process of sensing and recording data on the region of interest at the time of interest. Integrated in this process is the design of the data acquisition mission, which consists of the specification of such things as flight time, altitude, sensor type, and sensor adjustments (e.g. exposure times and F-stop settings for aerial cameras). These parameters must be carefully matched to the problem at hand.

Data manipulation consists of putting the information obtained by the remote sensor system into a form suitable for analysis or interpretation.

Information extraction is the actual analysis or interpretation of the remotely sensed data to obtain the needed information. This step may be, and many times is, closely associated and integrated with the data manipulation.

Information presentation consists of putting the extracted data into a form in which they can be used to assist in solving the problem at hand. The most useful form for a particular set of data depends, of course, on how those data are to be applied to the solution of a problem.

Although there are certainly limitations in the state of the art of implementing each of the previously discussed steps, perhaps the most serious limitation has been in the ability to effectively plan remote sensing missions.

The information content of a remote sensor image is contained in the variations in tones (or colors) that appear on the image. The investigator must place the tones and their patterns into some meaningful context to translate them into the desired information. It would be ideal if variations in image tones were always directly and exclusively related to changes in terrain material types (e.g. soil or vegetation types) or conditions (e.g. soil moisture content or water turbidity). Unfortunately, this is seldom the case. At best, image tones are related to the reflectance or radiation properties of materials, which may or may not be directly related to the information desired by the investigator. Additional uncertainties are added in that the atmosphere, the sensor components, and geometric relations can have considerable influence on image tones. It is entirely possible that image tones can vary without changes in terrain conditions and terrain conditions can change without producing a change in image tone. Better planning of remote sensing missions requires a simple but comprehensive means for collectively considering the impact of the many complex phenomena involved. The mission planning procedures developed are intended to provide this capability.

![Figure 1. Concept of Photographic Systems Simulation Model](image-url)
Photographic Mission Planning Procedures

The Photographic Systems Simulation Model is a computer program that predicts the performance of photographic systems and is the mainstay of the procedures generated to plan photographic remote sensor missions. The basic concept of the model is illustrated in Figure 1. In the figure the data-acquisition problem illustrated consists of distinguishing between cottonwood and fir trees; however, the features may just as well have been two masses of water with different turbidity levels, or indeed any combination of natural or man-made features or conditions that the investigator wishes to distinguish on the imagery. Using the sun as the basic energy source, the model calculates the energy reaching the remote sensor (at some prescribed position) by considering the scattering and absorption characteristics of the atmosphere, the reflectance characteristics of the features being considered, and the energy source-terrain-sensor geometry. The energy reaching the sensor for a feature and background (or second feature) interacts with the components of the sensor system (the lens, filter, and film for photographic systems) to predict the contrast in image tones (optical density contrast) that would be expected between the feature and background for each sensor (lens-film-filter) considered.

Figure 2 presents an example of the output of the model. The first column (on the left) indicates the film type, the center column indicates the filter, and the column on the right gives the predicted optical density contrast values (for each film-filter combination considered) for the feature, background, atmospheric condition, solar zenith angle, and sensor altitude given in the legend. The color (2448) and color infrared (2443) films have three emulsions (cyan = C, yellow = Y, and magenta = M); optical density contrast values are predicted for each emulsion individually and these values can later be combined for comparison with the predicted values for the single-emulsion films. An optical density contrast value of approximately 0.30 approximates the minimum contrast required for easy discrimination by the human eye.

In addition to the output shown in Figure 2 the model considers the dimensions of the feature(s) of interest, the spatial resolution characteristics of the sensor (camera), and the distance between the sensor and the feature to determine whether the feature(s) would appear as a discrete item (based on size only) on the resulting imagery. Figure 3 is an example of the type of information resulting from these calculations.

The only essential inputs for execution of the model are spectral reflectance curves for the feature and background (a second feature) of interest. A spectrum of atmospheric conditions, sensitivity characteristics for a spectrum of commonly used films, and transmission characteristics for commonly used filters are on file for use in executing the program. Thus, for predicting the optical density contrast values expected for waterhyacinth and spatterdock aquatic plants (see

<table>
<thead>
<tr>
<th>Film</th>
<th>Filter</th>
<th>Optical Density Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>2402 Plus-X Panchromatic</td>
<td>12 Yellow</td>
<td>0.017221</td>
</tr>
<tr>
<td>2403 Tri-X Panchromatic</td>
<td>12</td>
<td>0.013127</td>
</tr>
<tr>
<td>2402 47B Blue</td>
<td>47B</td>
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<td>2403 47B</td>
<td>47B</td>
<td>0.164144</td>
</tr>
<tr>
<td>2402 58 Green</td>
<td>58</td>
<td>0.079427</td>
</tr>
<tr>
<td>2403 58</td>
<td>58</td>
<td>0.079427</td>
</tr>
<tr>
<td>2402 25A Red</td>
<td>25A</td>
<td>0.032514</td>
</tr>
<tr>
<td>2403 25A</td>
<td>25A</td>
<td>0.014665</td>
</tr>
<tr>
<td>2402 3 Haze</td>
<td>3</td>
<td>0.063758</td>
</tr>
<tr>
<td>2403 3</td>
<td>3</td>
<td>0.043076</td>
</tr>
<tr>
<td>2448C Color*</td>
<td>3</td>
<td>0.000578</td>
</tr>
<tr>
<td>2448Y</td>
<td>3</td>
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</tr>
<tr>
<td>2448M</td>
<td>3</td>
<td>0.104692</td>
</tr>
<tr>
<td>2443C Color-infrared*</td>
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<td>2443Y</td>
<td>3</td>
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<tr>
<td>2443M</td>
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<tr>
<td>2443Y</td>
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<tr>
<td>2443M</td>
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<tr>
<td>2424 Black-and-white infrared</td>
<td>12</td>
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<tr>
<td>2424 25A</td>
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<td>0.202076</td>
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<tr>
<td>2424 87C Infrared</td>
<td>87C Infrared</td>
<td>0.173644</td>
</tr>
<tr>
<td>2424 87B Infrared</td>
<td>87B Infrared</td>
<td>0.213561</td>
</tr>
</tbody>
</table>

**Figure 2. Typical model output**

LEGEND
Feature: waterhyacinth: Black Creek, Fla.
Background: spatterdock: Black Creek, Fla.
Atmosphere mid-latitude summer haze: 23 km
Zenith angle: 30 deg
Distance to sensor: 1.50 km
* C, Y, and M represent the cyan, yellow, and magenta emulsions, respectively, for multiple-emulsion color and color-infrared film.

**Figure 3. Resolvable ground distance as a function of altitude for Kodak Plus-X AeroGraphic Film No. 2402**
only the reflectance data as shown in Figure 4 are needed for input. These data may not be readily available in the literature; because reflectance properties of terrain materials change seasonally (e.g., vegetation) or with changes in moisture (e.g., soils), it is often necessary to acquire these data by field measurements. Portable radiometers are available to simplify this task. It may seem inconvenient at first to have to collect reflectance data; however, this is a small price to pay for imagery having the information desired. It is extremely costly both in money and time to refly missions until the information needed is acquired. Indeed, in some instances it is essential to acquire the needed data the first time.

Because not all potential users have computer facilities available to execute the Photographic Systems Simulation Model, a two-part nomogram has been developed to provide all users with a graphical means for evaluating the performance of photographic remote sensors. The nomogram is documented in Reference 3 and, as is the case with computer program version of the model, requires only reflectance data for its execution.

**Application of Procedures**

The ability to predetermine the expected performance of a number of sensor systems for a specific data acquisition job is a powerful capability. This capability could be applied to: (a) determine if it is feasible to acquire the desired data, (b) pick the best sensor (e.g., film-filter combination), and (c) determine an acceptable mission profile (e.g., altitude, time of day, etc.).

Determining if the desired data can be obtained by photographic systems and making at least an initial selection of the best film-filter combination can be as simple as acquiring reflectance data for the feature and background of interest and executing the model (computer program or nomogram) with these data. The model output in Figure 2 might be the basis for deciding if photographic systems can be used to discriminate between waterhyacinth and spatterdock, two aquatic plants that infest waterways and inhibit navigation. Examination of the predicted optical density contrast values in the figure reveals that none are above the 0.30 value previously cited as necessary for discrimination by the human eye. The yellow emulsion of color film (2448Y) with a haze filter (3) has a predicted contrast value of 0.27 which coupled with the 0.10 value for the magenta emulsion (2448M) would probably produce a combined tonal change sufficient for visual detection. So in this case we might say that color film with a haze filter will allow discrimination of the two aquatic plant species. In addition, it is obvious that the color film-haze filter combination would be the best for the job.

Determining an acceptable mission profile requires examination of the effects of variations in the pertinent parameters on the expected optical density contrast values (in this case for the color film-haze filter combination). This may involve executing the model using a spectrum of the atmospheric condition, solar zenith angle (analogous to time-of-day), and sensor altitude options available. The predicted contrast values can be examined to determine the relative effects of each parameter. If, for example, an increase in sensor altitude (distance to sensor in the legend in Figure 2) decreases the expected contrast significantly (below an acceptable level), the altitude at which the mission is flown must be tailored to maintain acceptable contrast. On the other hand, if an increase in altitude does not affect the expected contrast significantly, the altitude can be selected on the basis of information such as that presented in Figure 3, which concerns the size of patches of waterhyacinth and spatterdock that the user wants to be able to discern on the resulting photographs. Similar analogies can be drawn for other parameters or combinations of parameters.
Summary

The procedures introduced are by no means all-encompassing, nor are they always needed. When they are needed, however, they provide a new dimension for systematic planning of photographic missions. The procedures are oriented toward the people who apply photographic sensors rather than those who design them. The computer program version of the Photographic Systems Simulation Model is currently on the WES computer and available for use. It is recommended that interested persons contact the author for a more thorough discussion of the procedures and their use. The cost of running the computer program is insignificant. Low-cost equipment for acquiring reflectance data is available at WES along with personnel skilled in its use.

References


PROTECTION OF POST-TENSIONING ANCHORAGES FROM THE EFFECTS OF SALT-WATER FREEZING AND THAWING, by E. F. O'Neil, Concrete Laboratory

At Treat Island, Maine, WES Concrete Laboratory personnel have been conducting field research into the effects of a corrosive environment on concrete and concrete reinforcing materials. This exposure station is located in Cobscook Bay near Eastport, Maine, and is an ideal location for providing the freezing and thawing saltwater environment that is highly detrimental to concrete. Specimens placed on the beach at Treat Island (Figure 1) undergo twice daily cycles of wetting and drying and, in addition, during the winter months experience over 130 cycles of freezing (temperature of the center of the specimen going below –1°C) and thawing (+1°C). This severe environment became the setting for a research project to determine the protective effectiveness of several types of posttensioning steel end anchorage coverings and methods of preparing the ends of concrete beams to accept these coverings.

The posttensioning method of prestressing concrete relies entirely upon end anchorage plates to transfer the posttensioning stresses from the steel to the concrete. Consequently, the protection of these anchorages from corrosion is of the highest concern. Steel, in itself, builds a protective coating of oxides on its surface that inhibits the process of corrosion. The chloride ion in salt water acts to destroy this passivating coating and permits further active corrosion to take place. With this film absent, water and oxygen combine chemically with the steel to corrode it. Without adequate protection to the steel, such as end caps or plugs over the anchorages, seepage of water and oxygen to the surface of the anchor and into the conduit housing the posttensioning wires will result. This will corrode the steel, causing spalling of the concrete, rust staining of the specimen surface, and, if allowed to continue, will result in deterioration of the steel to the point of loss in posttensioning forces, failure of the posttensioning wire, and ultimately destruction of the specimen itself.

To learn ways to combat this problem, WES placed 20 posttensioned beams on the beach at Treat Island to observe the protection provided the end anchorages by
the type of end anchorage protection each beam received. There were four different posttensioning systems represented in the 20 beams. There were two different types of end protection to the anchors. On some beams the end anchor was external to the end of the beam. These ends received concrete end caps as protection. Some of the ends of the beams had recesses for the end anchorage. These ends received an end anchorage protective plug to fill the recess. The mixtures used to make the caps or plugs varied with the beams. They were either portland-cement concrete, sand-cement mortar, or an epoxy concrete in which the cement portion of the mixture had been replaced by epoxy. Whether the anchorages were protected by end caps or plugs, the joint between the end protection and the beam was prepared to receive the end protection by one of the following preparations: bush hammering the surface, a retarding agent added to the end of the beam to aid in roughing the surface, an epoxy coating to the joint, or no treatment at all.

During the exposure period the beams were inspected annually by a team of investigators who rated the performance of the end protective methods according to spalling resistance, freeze/thaw resistance, rust staining on the surface of the joint, and the integrity of the joint between the beam and anchorage protection. Each end anchorage was given a yearly numerical rating. The ratings ranged from 0 for a perfect condition to 28 for a totally failed end cap or plug.

Eight of the beams were brought to WES for testing and autopsy to determine the condition of the steel wires and anchorages beneath the end protections. From the autopsy of the beams the condition of the steel wires ranged from uncorroded to mildly corroded and the anchorages ranged from uncorroded to heavily corroded. Some of the end protection caps or plugs had become completely dislodged (Figure 2) and others were in excellent condition.

The observations made during long-term exposure testing, coupled with the testing and observations that have been done in the laboratory, have yielded some important information about protecting end anchorages of posttensioned beams. When the anchorage protection is of the flush plug type rather than the external cap type, there is less anchorage protective material exposed to the weather and the joint between plug and beam is smaller. This condition affords less surface area for seawater to enter the end of the beam through the protective plug, and the action of freeze/thaw can do less harm. Due to the nature of the
material, both the epoxy concrete end caps and plugs have almost no air voids in their matrix. Since there are no voids or passages, water and oxygen cannot penetrate to the anchorage and, consequently, this mixture afforded greater anchorage protection than portland-cement concrete. The purpose of preparation of the end of the beam to receive a cap or a plug was to provide a roughened surface to obtain better bond between beam and end protection. The method of end protection with which there were the least number of failures of cap or plug was the method of adding a retarding agent to the end of the beam and roughing the retarded cement before set occurred. This type of preparation provided an improved surface to bond to, and less failure of the joint due to freezing and thawing.

RESEARCH REPORTS

Concrete Laboratory:


Hydraulics Laboratory:


Transmission of Wave Energy Through and Overtopping of the Long Beach, California,


**Mobility & Environmental Systems Laboratory:**


**Soils & Pavements Laboratory:**


Usage of Landing Mat as Overlay on Asphalt Runway During Military Field Exercises, by H. L. Green, Miscellaneous Paper S-76-24, Dec 1976.

**Weapons Effects Laboratory:**


**Environmental Effects Laboratory:**


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