35-mm Photography: An Inexpensive Remote Sensing Tool

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ABSTRACT: Remote sensing has long been recognized as a valuable tool for monitoring environmental change. Conventional environmental monitoring systems have included Landsat, and high- or low-altitude photographic imagery. Applications have generally been restricted by the requirement for cartographic precision of analyzed data. There are circumstances, however, when a quick low-cost data acquisition method can be more useful than more traditional photogrammetric methods.

This paper describes systems and methods whereby basic photogrammetric principles can be applied to the use of simple, inexpensive equipment to obtain photography comparable in utility to much more costly work produced by conventional equipment and procedures. Special attention is given to applications in the Arctic. Hand-held 35-mm camera equipment used with fixed wing or helicopter aircraft can gather imagery which is more than adequate for reconnaissance, pollution monitoring, and documentation of events.

REMOTE SENSING REQUIREMENTS IN NORTHERN ALASKA

THE ALASKA NORTH SLOPE REGION includes all of the land within the state north of the Brooks Range. The area can be divided into three distinct provinces—the Brooks Range, the rolling foothills, and the coastal plain. This discussion focuses on the coastal plain where oil and gas exploration has occurred during the past 30 years. The region is remote, accessible by ocean-going barge for approximately six weeks during the summer, by overland vehicle during the winter months, and by aircraft during most of the year. Until the haul road associated with the TransAlaska Pipeline was constructed in 1974, there was no year-round overland access to the region. Further, the road serves only the Prudhoe Bay, Kuparuk, and Endicott developments in the midsection of the region. The road network does not extend to any of the villages in the area.

Land use in the region is regulated by the Federal, State, and local governments, with a considerable amount of overlap in regulation. The problem of land-use regulation is compounded by an extremely active environmental lobby and a general fascination for Alaska throughout the other states. Because of regulatory requirements, public curiousity, and the relative newness of industrial activity to the region, developers have been careful to insure that impacts to the region have been kept to a minimum.

Weather in the region has been an obstruction to acquisition of low-level photography and preparation of detailed mapping products. Survey crews must be transported into the area by aircraft. Surveyors' work is hindered by continuous winds and chilly temperatures. Average July temperatures on the North Slope are between 40° and 45° F. When the wind stops, mosquitos come out in droves. Along the coast, fog occurs 115 days during the year, mostly during the summer months. When the fog does lift, it rises to 1,000 to 2,000 feet, limiting attempts to obtain aerial photography to a few clear days during the summer months. The first snowfall occurs during September and snow cover remains in many areas well into June.

The U.S. Geological Survey mapped the region at a scale of 1:250,000 in 1955. Few updates have been made to the map series because of weather, budgetary limitations, and government priorities.

Because costs of obtaining detailed photography, with or without control, in large areas of the North Slope are prohibitive, developers in the region have limited acquisition of low level photography and preparation of detailed mapping to areas where oil and gas development is occurring. In order to plan for exploration activities outside of the "development core," companies must plan to obtain large-format, low-altitude aerial photography well before plans for specific drilling activities are firm, or must find an alternative means of obtaining photography.

The discussion that follows describes application of hand-held, small-format photography to meet the requirements of the oil and gas industry in northern Alaska. Hand-held imagery has been used to define baseline conditions, to monitor construction activities, and to identify changes in environmental conditions resulting from oil and gas activities.

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APPLICATIONS

Routine work requirements within many industries require acquisition of detailed, time-specific information. This is particularly true in the forest products industry where small format cameras are routinely used for remote sensing and mapping. This photogrammetric tool may be applied to development planning and to environmental monitoring as well. Further, hand-held photography offers the advantage of flexibility when qualitative, rather than quantitative, data are required.

Specific applications in arctic Alaska include

- *Monitoring for historical purposes*. Photographs capture information for interpretation at a later date or that can be used as permanent records. Imagery can be interpreted to detect gradual changes—either degradation or restoration—at the earliest possible time. Many subtle changes would go unnoticed for significant periods of time if accurate baseline information were not available.
- *Predictive monitoring*. We have used a small format camera for remote sensing which helped to assure continued availability of a potable water source that would be lost if a nearby dike failed. Monitoring of erosion along the toe of the earthfill dam continues to insure early detection of leakage.
- *Monitoring to correct design problems*. Despite best efforts of hydrologists and engineers, culverts may be constructed in a manner that results in disruption of drainage patterns. Low altitude infrared photography has been used to identify areas where subtle changes have occurred to drainage patterns following installation of facilities. Modifications to facilities at the earliest possible time has resulted in minimization, if not elimination, of long term degradation of the environment.
- *Monitoring construction projects and other activities*. We have used infrared false-color photography to monitor offshore construction activities. This was particularly useful in identifying the limit of silt plumes associated with construction of gravel islands. It has also provided useful information regarding cleanup requirements and documentation of construction progress.
- *Monitoring and documentation of processes such as stream erosion and spring breakup*. Documentation of flood events and other seasonal changes is useful in insuring crew safety and in designing new facilities.

We have used a 35-mm hand-held camera system for monitoring construction activity and environmental changes associated with specific Alaskan north slope oil production facilities over a period of several years. Both conventional color and false-color infrared photos have been collected annually to document environmental conditions and to identify changes which have occurred over time. Obtained from helicopters, these photographs have subsequently been interpreted and archived. Where appropriate, the data acquired in this fashion have been used as a basis for recommendations for remedial action or in support of recommendations that no restoration work is necessary.

Photos of the near-infrared spectrum show a distinctive shift in color which helps flag changes in vegetation, changes in water quality, or similar characteristics. For example, healthy growing green plants appear as bright red in false-color IR photography. Mature (brown) grasses appear a brown or gray color. Deep, clear water bodies appear nearly black, while shallower ones are shown in varying shades of blue. Turbid waters are readily identifiable by gray or pale blue plumes consistent with the dispersion pattern of the silt in the water. Bodies of water containing algae appear more purple or magenta than do similar waters without algae. Some types of pollution in water produce a milky blue-green image on false color infrared film. The color shifts in the near infrared range allow photointerpreters to identify areas of vigorous vegetation for environmental analyses required for site and route selection or other work; to identify limits of disruption to aquatic habitats (by defining the limit of the plume); and to note other changes, regardless of their cause.

Simple, inexpensive photographic techniques which assist in identification of areas requiring further study encourage more efficient utilization of research and monitoring budgets. The information acquired in this manner is qualitative in nature. Its primary function is to provide evidence of no change to the environment or to identify areas that require more specific monitoring programs or rehabilitation efforts.

AERIAL PHOTOGRAPHIC PROCEDURES

Although wing mounted cameras are frequently employed to acquire aerial photographs from small planes, excellent vertical (or near vertical) imagery may be obtained through the nose bubble of a Bell 206 helicopter (more commonly known as a Jet Ranger). Oblique photographs may be acquired through side windows of fixed wing or helicopter aircraft. In either case, photographers have the advantage of selecting targets as they go. This flexibility in mission execution is useful. It does not, however, supplant the need for carefully prepared flight plans. The flight plan should include

- A list of photographic targets and film requirements.
- Maps marked with the most economical flight path. The maps help avoid unnecessary circling and the resulting questions regarding whether a particular site has been photographed or not.
- A checklist of equipment, including extra batteries, lens caps, battery chargers, etc.

Pre-mission planning will also permit more accurate estimates of materials needed (including film, batteries, and filters), flight time, and overall costs for the work.

The composition of the photographic crew might vary depending on the size and complexity of the mission. A half-dozen photographic shots might be handled by one person—even if that person is also the pilot. A more complex mission, however, will be handled more efficently by two persons in addition to the pilot.

Each member of the project team has specific assignments. One, whom we call the "navigator," will be available to check off items on the flight plan, change film, make notes of sites to be photographed on a second pass, etc. The other person, the "photographer," devotes full time to using the camera.

The navigator should be someone who has a depth of understanding about the objectives of the mission and some familiarity with the target areas. For example, if the purpose of the trip is to obtain documentation of pollution, an environmental professional would be a good choice, while a mission to document construction progress might use a construction engineer in this role.

The photographer must be thoroughly practiced in the operation of the camera equipment, but there is also an advantage if this person has professional qualifications and experience related to the mission. Recognition of photographic targets will be facilitated as will communication with the navigator. Continuing the examples used above, an environmental scientist with arctic experience would probably respond appropriately to a request from the coordinator to "get a shot of the turbidity around that stand of *Arctophila fulva*" (a wetland species considered by wildlife biologists to be important to waterfowl). A civil engineer would likely be sensitive to the need for a photograph of ponding upstream from a newly placed culvert. A professional photographer unfamiliar with environmental concerns and construction activities at the site might well miss both shots.

Regardless of the makeup of the team, it is important that the pair be able to communicate well with each other and with the pilot. It is useful to take 10 or 15 minutes before boarding the aircraft to review the entire flight plan and project objectives with the pilot. A professional pilot, with or without remote sensing experience, can contribute to the project if he understands what the team is trying to accomplish.

If possible, the aircraft should be equipped with an open-channel or voice-actuated intercom system with headsets and microphones for all participants. If only one voice-activated mike is available, it should be provided to the photographer who already has his hands full. If an intercom system is unavailable, hand signals should be worked out in advance. An additional technique for flights with inadequate communication systems is to break the mission at regular intervals to review the next work increment. Regardless of communication tools available, the team should not hesitate to take a break to discuss how the work is going and what additional tasks are to be accomplished. A few additional minutes of air or ground time taken for discussion among the team can make the difference between a successful mission and one that must be repeated when the film comes back from the processor.

CAMERA EQUIPMENT

Equipment for the project includes a 35-mm camera body, one or more lenses, and a built-in or external light meter. Optional equipment includes motor drives, magazine backs, data backs, automatic metering devices, intervalometers, and filters. Configuration of the camera system is dependent upon budget and photographic requirements. the camera system used by the authors for environmental monitoring is shown in Figure 1.

A considerable amount of work can be done with an inexpensive single lens reflex camera with a 28- or 50-mm lens and a filter appropriate for the film. For larger projects a magazine back (for up to 250 exposures) is invaluable. Where stereo pairs are required, an intervalometer may be useful. As with conventional aerial photography, altitude, focal length, and exposure interval can be coordinated to give the desired image size and percent overlap.

Each of these pieces of equipment, accessories, and film are discussed in detail below.

- *Camera*. The 35-mm camera used for aerial reconnaissance should have a high-speed shutter in order to avoid loss of sharpness stemming from vibration of the aircraft. Either a single lens reflex or rangefinder camera can be used effectively. For infrared work there may be some advantage to using a rangefinder camera because the photographer's view of the subject will not be obscured by the deep yellow filter mounted on the lens. On the other hand, the advantages of through-the-lens viewing may outweigh any inconveniences resulting from the darkened lens. With a rangefinder camera, the photographer must be aware of potential parallax problems. He may have a clear shot through his rangefinder, but have the camera's field of view partially blocked by part of the aircraft. With an SLR, what he sees is literally what the photographer will get. In difficult lighting situations where there is glare from aircraft windows, the SLR makes the photographer aware of potential problems so he can correct for glare during the flight. Often, window glare can be eliminated by moving the lens slightly closer to the window or by

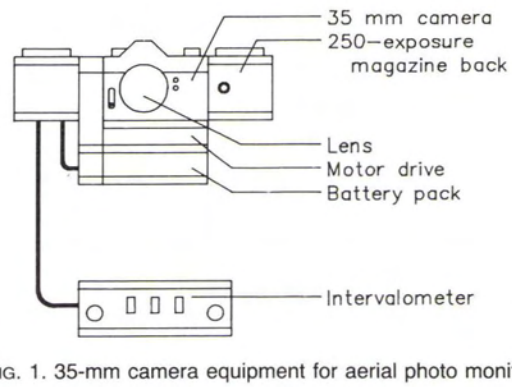

FIG. 1. 35-mm camera equipment for aerial photo monitoring.

draping the photographer and camera with a jacket or blanket to stop light passing over his shoulder.

- *Light Meters*. The most simple mechanism for metering is to use an SLR camera with a built-in meter. Because these meters measure the light that actually reaches the film plane, no calculations are necessary to determine appropriate camera settings for lighting conditions. Cameras with automatic metering systems are attractive for use in this type of aerial surveillance work, especially if the metering system has aperture priority.
  Although it is an expensive enhancement, a servo mechanism may be employed to convert a manual metering system to an automatic one. In northern Alaska we found that automatic metering was convenient, but not necessary. When weather conditons are appropriate for aerial surveillance photography, lighting conditions change little, if any, over a period of 10 or 15 minutes, so an occasional check of the light meter is sufficient to maintain the proper exposure.
- *Motor Drives*. A motor drive is essential in hand-held aerial photograph. It allows a photographer to obtain several good exposures of a site in one pass over it. By simplifying the operation of the equipment, it also encourages the photographer to focus attention on the sites being evaluated, rather than concentrating on camera operation.
- *Lenses*. Although 50-mm or longer focal length lenses may result in less distortion across the film frame, longer lenses necessitate higher flight altitudes. When ceilings are low, as they often are in the arctic, wide angle lenses are particularly attractive. Shorter focal length lenses (28-mm or 35-mm) require the photographer to take care to avoid shots of window frames or other aircraft parts. In the arctic, where cloud coverage is present at an altitude of 1,000 to 2,000 feet throughout most of the summer days, the flexibility of a shorter lens is valuable. Regardless of what length lens is chosen for a particular project, it should be a relatively fast one to avoid any loss of definition resulting from aircraft vibration.
- *Filters*. For false-color IR (EKIR) and Kodak Aerochrome films, a Wratten 12 filter (dark yellow) does a fine job. As a matter of course, the authors maintain neutral density filters on all lenses to protect them from dirt and damage. A polarizing filter may be used successfully with IR films. The combination of polarizing filter and aircraft window (generally plexiglass or coated safety glass) may result in a moiré pattern. In an on-the-ground test, a polarizing filter improved the quality of photographs taken at ground level in wetlands where reflections from ponds had resulted in glare.
- *Data Backs/Magazine Backs*. Because of the high cost of aircraft rentals and the relatively low costs of film and processing, it makes sense to take lots of pictures. However, labeling and sorting large numbers of photographs is a chore at best. Data backs are particularly useful in recording the time and date, if not the location of each photograph, saving considerable time and effort later. Magazine backs eliminate the need to change film frequently. They provide continuity to the project and eliminate the chance of error in numbering sequential rolls of film. They also permit the photographer to make a large number of exposures with a minimum of costly time spend changing film. If a magazine back is not utilized, a second camera is a good investment. The navigator can reload one camera while the photographer is using the other.
- *Intervalometers*. Where stereo pairs may prove useful to photo interpretation, or when a roadway, pipeline, or other linear feature is to be photographed in its entirety, an intervalometer may be useful. The authors found in conducting powerline inspections that the photographer could judge exposure overlap with some precision. And, considering the complex calculations required to obtain proper overlap using an intervalometer and the relatively high cost of the equipment, occasional users are better off estimating overlap for stereo pairs.
- *Batteries*. Every battery added to a camera system provides another opportunity for mechanical problems. Although rechargeable batteries are available for most accessories, there is no substitute for installation of fresh batteries throughout the entire camera system at the beginning of each photo mission. The cost of fresh batteries is extremely low compared to the cost of aircraft and personnel for a photographic expedition. Spare batteries should be carried for all battery-operated equipment.
- *Film*. For occasional short trips, Kodak EKIR is available at most camera stores. Kodak Aerochrome provides superior color for environmental monitoring purposes. It is not easy to obtain, however. The authors have been able to purchase 35-mm bulk Aerochrome film from a forestry school that teaches remote sensing. Processing for long (in excess of 36 exposures) rolls of either of these films must be done by a specialty lab. Regardless of the choice of film, a test roll should be exposed and processed before each season begins. Exposures should be bracketed to assure that field reconnaissance is done with appropriate camera settings. A preseason expedition is an excellent time to refamiliarize the photographer with the camera as well. True color films are also useful for environmental monitoring. A relatively fast film (ASA 100 or higher) with a fine grain should be selected for hand-held photographs. A wide variety of both slide and print films is available. True color film for aerial reconnaissance should be selected in the same manner that film is selected for recreational purposes—photographers choose films with which they are comfortable and that have provided them with good pictures in the past.
- *Equipment Cases*. Camera cases for equipment to be used in the field in general, but in aircraft in particular, must be easy to use in small spaces. No helicopter or small-sized fixed-wing aircraft has space to open suitcase-type camera carriers. The authors use aluminum cases to ship larger camera gear as luggage on passenger aircraft, but utilize compact, over-the-shoulder, top-opening bags in the field.
- *Tape Recorder*. A small, portable tape recorder will help the navigator collect oral information while in flight. This, together with the flight plan and check list of sites to be visited, will greatly assist interpreters in identifying particular photographs and summarizing data acquired.

CONCLUSION

The advantages to small-format, hand-held camera systems are many. The camera system itself is easy to operate; in fact, most adults have used a 35-mm camera at one time or another. The systems are portable and flexible. They can be used for aerial photography and for ground insections of construction sites or other areas.

Small format photography offers an alternative to conventional aerial photography, particularly when inspections are to be conducted. It costs very little to take a camera along, and project flexibility is enhanced when researchers are in the field directing exactly what imagery is to be acquired. "Opportunity" photographs provide additional insight to monitoring programs of any sort. It is extremely difficult to identify each particular photographic target from an office or on the ground.

Hand-held photographs will generally not provide quantitative data except in gross terms. The qualitative data that are easily collected, however, far surpass any disadvantages of lack of control for mapping purposes. When precise geographic positioning is not required or when it can be obtained by correlating features on photographs with the same features on conventional photogrammetric images, a great deal of data can be derived from hand-held photographs.

Photographers/researchers know exactly what imagery they have acquired at the time they snap the pictures. They have the opportunity to acquire additional detail while they are in the field. That flexibility is lost when imagery is collected by a contractor who focuses his camera at several sites on a map without knowing exactly what the purpose of his work is.

Hand-held photographs are as versatile as the photographer who takes them. They have application in many professional disciplines including environmental monitoring or research, engineering, construction, and planning.

A 35-mm aerial photography system can be useful where there is an occasional or seasonal, rather than a continuous, need for documentation of the development history of certain conditions. The initial outlay for equipment is relatively small, and the operating cost is much less than that of conventional controlled aerial photography.

An important reason why hand-held 35-mm aerial photography is more economical than conventional photogrammetry relates to the weather. When weather conditions such as low ceiling delay a conventional aerial photographic mission, the time is essentially wasted because crews and aircraft do not ordinarily have alternative tasks. On the other hand, professional staff persons who normally have other assignments, but who do aerial photography on a periodic basis, will be able to schedule their tasks to be beneficially employed while waiting for a break in the weather. Furthermore, mission planners faced with obstinate weather conditions may elect to modify plans, e.g., by flying at a lower altitude. Such plan changes would be unusual where changes would be required to a formal contract with an aerial photography firm.

Erratum

In the article, "Separability of Boreal Forest Species in the Lake Jennete Area, Minnesota," by Shen, Budhwar, and Carnes (*PE&RS*, November 1985, pp. 1775–1783), the following paragraph should be added to the Acknowledgment (p. 1781):

The work reported in this paper is part of a larger joint project between the University of California, Santa Barbara, and the Johnson Space Center (JSC), Houston, Texas. Professor Daniel Botkins and Dr. Kerry Woods (UCSB) and Robert B. MacDonald and Dr. Forrest G. Hall (now at Goddard Space Flight Center, Greenbelt, Maryland) were the principal investigators. The ground based data, such as tree areal density, diameter at breast-height, and dry and wet biomass of leaves, stems, and boles, were collected by the UCSB team. These measurements were provided to Dr. Al Feiveson (JSC) and formed the basis of leaf area index calculations quoted in the text. We would like to thank Professor Botkins and Dr. Kerry Woods for the initial impetus for this work and for providing their unpublished data on the test sites.