# Obtaining and Using Low-Altitude/ Large-Scale Imagery

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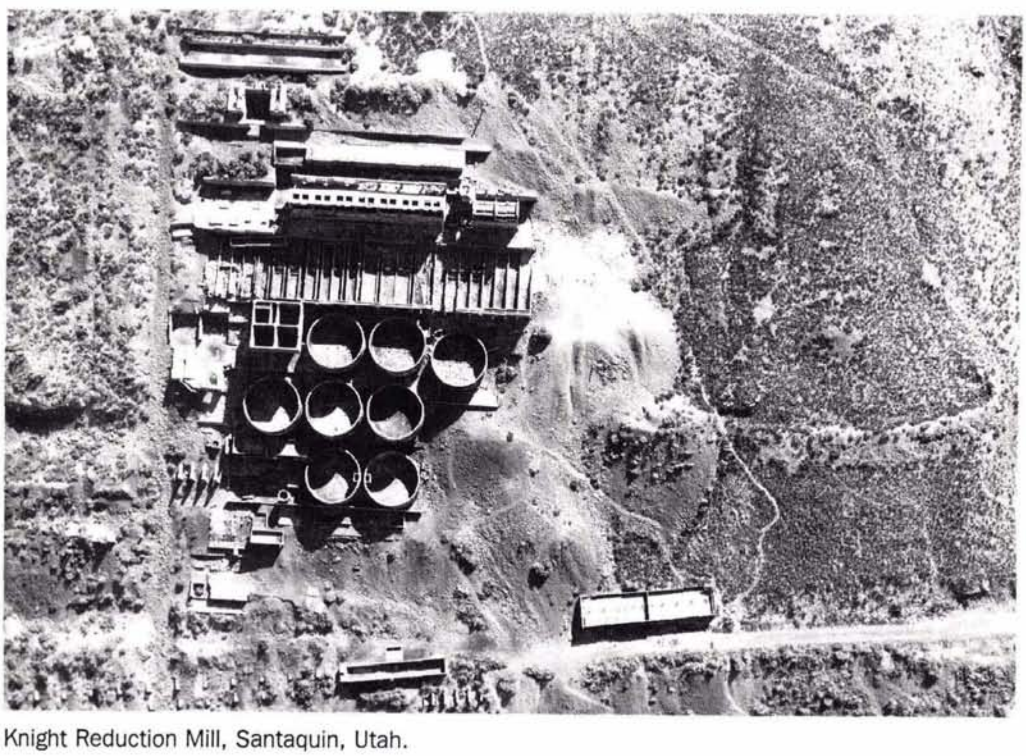
In contrast to the current trend for remote sensing to use smaller scale satellite imagery for large areas, we have been working with imagery with an average scale of 1:330; these images cover less than a pixel on current satellite scenes. The critical resolution of these images is 0.187 inches. Low-altitude/ large-scale imaging techniques extend the capability of remote sensing. Let it be noted at the outset that what we are doing is not "more of the same": low-altitude/ large-scale is a radical departure from the past. Unfortunately it has been customary to use two different terminologies (scale and pixel size) to describe scale on aerial photographs and satellite images. To overcome this problem we have coined the phrase, "critical resolution" and used it as an expression of the image motion problem. Film resolution has not been the critical factor during the last thirty years. When we report that the critical resolution of our latest platform is 0.187 inches, this is in contrast to 5.3 inches for a nine-inch mapping camera and 394 inches for SPOT imagery. There is a tendency to suppose that all that need be done to get better resolution is to go to a longer focal length. This assumption overlooks the fact that neither altitude nor focal length enter into the image motion equation. Image motion is dependent solely on the forward motion of the camera while the shutter is open. It is measured in earth-object sizes and is not scaled. Thus, on low-altitute/ large-scale imagery, objects of only three-sixteenths of an inch will be sharply imaged on film without any image motion blur. Large scale, in our case, is a 3.5- by 5-inch print with an optimal scale of 1:330. When this is enlarged 20 diameters, the scale is approximately 1:20. Even at this scale we do not get image degradation due to grain structure of the film.

Students, having learned that scale is dependent upon focal length and altitude, have a hard time conceptualizing that image motion is solely dependent upon camera shutter speed and ground speed of the camera platform. (IMP = 17.6 × aircraft velocity in mph × shutter speed in seconds.) To put this in persepective, a nine-inch mapping camera has a shutter speed of 1/500th of a second. At the altitudes flown, this is the fastest shutter speed that can be used for the available light; hence the 5.3-inch critical resolution at normal aircraft

**...what we are doing is not "more of the same"**

velocities. On the U-2, two-second exposures were not uncommon, but since the film resolution was on the order of 17 to 18 inches, image motion compensation was not used on the catadioptic cameras. On the high-speed tactical reconnaissance platforms using



Knight Reduction Mill, Santaquin, Utah.

UUT model airplane.

image motion compensation, a critical resolution of 3 inches is common. It would be possible to build a framer with 1/1000th second shutter speed that a Mach one would deliver one-half inch critical resolution but the cost would be $7 million plus. (Most of these data can be inferred from a careful reading of Burrows, William E. 1986. *Deep Black*. New York, Random House.)

We began twenty years ago with a balloon-mounted camera. Imagery of the Knight Reduction Mill, abandoned fifty years earlier, was requested at a scale of 1:1000. The camera mounting arm was loaded with powerful magnets so that the camera would take directionally aligned photographs. We discovered that our area is almost never wind-free. The tether acted as a pivot arm, blowing the balloon and camera into the ground. We lost a lot of helium, but fortunately no cameras. Craig Harmon, a student in archaeology, after an ardous winter of reconstructing field notes, wrote a paper detailing the rationale for photographing an archaeological site several times a day to assist in the reconstruction of the field notes. This concept was scorned by archaelogists who insisted that a great deal of time would be wasted cleaning the site every time an aerial photograph was taken. Excavation photographs have never been the same since.

Given the limited success of the balloon-mounted camera we tried mobile cranes (cherry-pickers) and camera tripods constructed from light-weight twenty-foot aluminum sprinkler irrigation pipes. The elevation limitations restricted both the scale and the utility of the photographs.

Woodward Mound, Goshen, Utah. The grid is the string provenance.

During all of this experimentation, we continued to fly light fixed-wing aircraft taking pictures from both hand-held and mounted cameras. Most memorable was the imagery of Etzna, Mexico, which when density-sliced, delineated for the first time the canal systems.

During the summer of 1980, a request was made for large-scale photographs of Woodard Mound and Old Goshen Town archaeological excavations. A differential density sponge and wood camera mount was designed, built, and tested for use with an ultra-light aircraft. To be within the safe-flight envelope of the aircraft, the

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Nancy Patterson site, SE Utah. Flown with ultralight.

weight limitation was 8.1 kg. The system as designed weighed only 5.4 kg. including mount, camera gear, and intervalometer. The results were visually superior and bordered on the sensational: we could clearly see the string marking the excavation grid. With a 12 mph headwind, the ultra-light flew both sites at a ground speed of 12 mph.

During the summer of 1984, flights were made with the same camera mount at the Nancy Patterson archaeological ruin in Montezuma Canyon, southeastern Utah. An uncontrolled mosaic was created from the imagery, which was acquired at minimal costs. Changes in the interpretation of ultra-light aircraft usage by the FAA between 1980 and 1983 halted much of the ultra-light aircraft use. As a result of this and risk management constraints we made the decision to explore the use of remotely piloted model airplanes.

In our search for low-altitude/large-scale imagery we learned that:

- Rotary wing aircraft are not cost effective for most university research projects. Excessive vibration causes blurring of the image. At low altitudes, vegetation is flattened, which obliterates the very subtle vegetational disturbance patterns that are essential to reconnaissance imagery. In addition, dust is created.
- Low-altitude reconnaissance eliminates haze problems.
- Image motion blur is minimal when the velocity of the reconnaissance platform is minimal (Caylor, 1989).
- Vibrationally induced blur is kept to a minimum when the camera is mounted in a multiple density sponge and wood mount.

For the rest of the eighties, we built and flew mostly Butterflies and some Telemasters. Our current airframe is the UU-2 with a 109-inch wingspan. On this plane the camera is internally mounted which has advantages over an external camera mount. We use a Ricoh RK 10m camera because it can obtain a shutter speed of 1/1000 second as well as electric film advance. We have used a variety of films. Generally we use the film with the highest resolution in lines per mm (Walker, 1992).

The principal user of low-altitude/large-scale imagery over the past two decades, and often the instigator of much research and development, has been anthropology/archaeology. We have done a great deal of work for the Department here at BYU as well as for the National Park Service. Many flights have been made for the purposes of reconnaissance, field recording, and deriving photogrammetric bases. Many times, these same images are also used by historical geographers. Low-altitude/large-scale imagery has potential for industrial archaeology, but at present the only relicted industrial site we have flown is the Knight Reduction Mill.

Recently low-altitude-large scale images have been correlated with magnatometry data collected by the National Park Service. While still in early stages, this appears to be a promising combination of remote sensors.

**This is not the poor man's approach to remote sensing.**

Walker recently flew reconnaissance imagery of Bent's Fort, Colorado, a major reprovisioning point on the Santa Fe Trail. Park Service officials wanted a record of the fort at present, to know the alignment and historic extent of the graveyard, to map the adjacent wetlands, and, if possible, to discover the race track. The imagery does show a race track and now it remains to discover whether this is in fact the early Nineteenth-Century race track or something later.

We have flown and are continuing to fly the Golden Spike National Monument at Promontory, Utah. The imagery of the Big Trestle shows vegetational differences indicating the placement of the footings for each major member of the trestle.

At a time when we were regularly flying Camp Floyd, a pre-Civil War army post in Utah, to field-record the stages of the excavation, someone else in another context wondered what the single white pixel at Fairfield,

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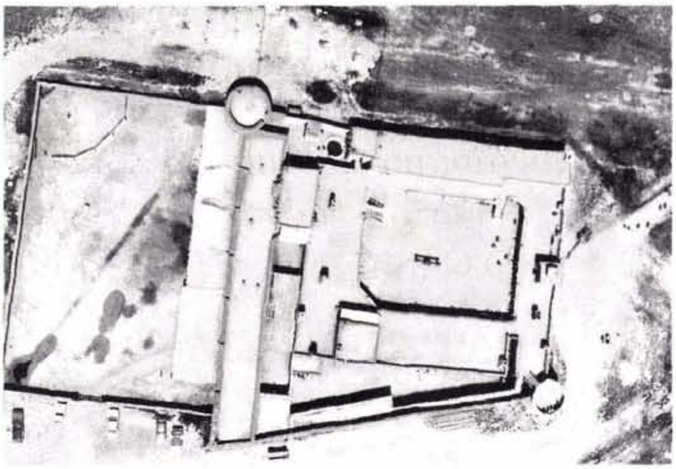

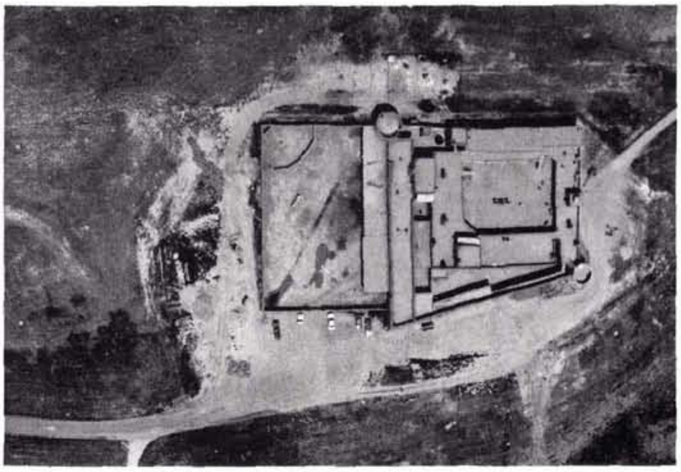

Bent's Fort, Colorado.

Utah, was that was showing up on the satellite imagery. This was the first time that we had realised that often our images covered about one satellite pixel.

We flew Cove Fort, the only surviving fort built by the LDS Church for the protection of early settlers, to help find the corrals, the barn, the outhouse locations, and the delineation of the reservoir. We have also flown bits of the Pony Express Trail.

With the advent of the analytical plotter it is possible produce photogrammetric base maps with contours. Because of the mechanical limitations of the analog plotters, it had not been possible to plot low-altitude/large-scale imagery because it was non-metrical and because of the base limitations. Pueblo Bontio, Chaco Canyon, New Mexico was plotted on an analytical plotter at a scale of 1:120. The wall at Chaco Canyon, which is subject to thermally induced movement, was plotted with three-cm contours.

For botany researchers, we have sequentially photographed areas of timber dead-falls on steep slopes to determine the rates at which logs are moved down-slope by gravity and by snow. We flew the new Provo City golf course to help determine what the emerging methane from the old land-fill was doing to the grass. From the imagery, it was determined that methane concentrations were the greatest where trenches had been dug for the sprinkler lines. The potential exists not only to do transects, but to record to amount of clipping/harvesting of bush leaves by herbivores.

Utah State University asked us to fly field plots where sprinkler irrigation trials were underway. Although researchers had set up a dense network of rain gauges, the corn, as it grew taller, tended to mask the guages and make the readings suspect. The imagery, on the other hand, showed subtle differences in the patterns of water distribution of the different sprinkler heads.

Golden Spike National Monument, Utah

Recently we have begun to fly engineering projects. EBASCO, a monitoring agency, requested low-altitude/large-scale imagery of the Utah County sanitary landfill because it did not show up on satellite imagery. From our imagery, it was evident that such a small area was open at any one time and that the surrounding area was so clean that it would not record on satellite imagery.

For the city of Pleasant Grove, Utah, we recorded the site of a new concrete culinary water storage tank, verified that the site avoided the spring-line, and sequentially recorded the construction.

We have recorded the site of the San Rafael Bridge, a single-span 160-foot break-away suspension bridge. It is designed so that in time of flood either end can be released and carried aside by the flood waters, obviating damage.

There is considerable potential for low-altitude/

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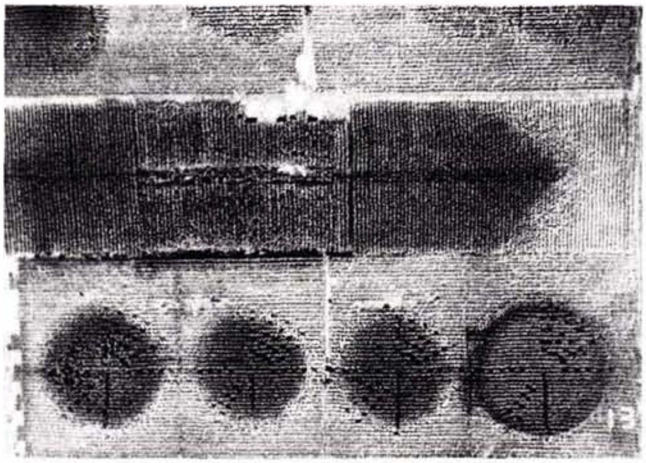

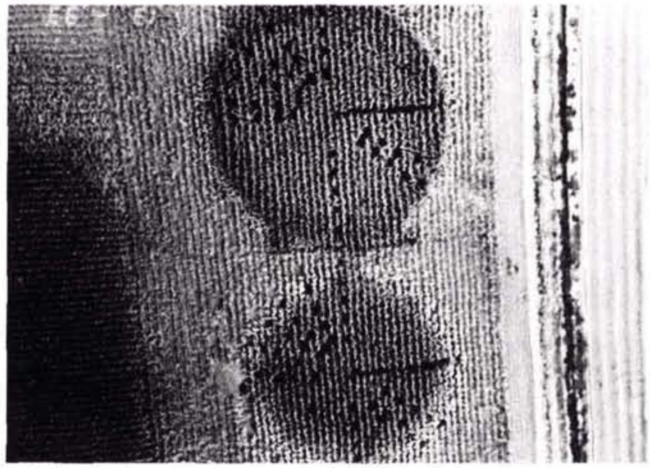

Sprinkler irrigation trials, corn, Utah State University, Logan, Utah. The holes in the corn are for precipitation gauges.

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large-scale imagery in recording and evaluating hazardous waste sites, but to date we have not participated in such a project.

There are many law enforcement possibilities for low-altitude/large scale. A student was flying the Spanish Fork River delta for his thesis. On the imagery was a plantation in the middle of a dense thicket of scrub, complete with a keg. It was reported.

With the benefits of low-altitude/large-scale have come some challenges. Our generation, starting in photo interpretation after World War II, learned the skills of photo interpretation from the many PI keys produced by the Army, Air Force, and Navy. As we acquired skill and a diversity of experience, we became less dependent on keys. When we started working with very large-scale imagery we were often completely baffled by parts of it. The first time we saw the wheel tracks of the photo aircraft take-off roll on the beach sand, we had no idea what we are looking at. We endlessly wished for a set of large-scale keys. In the end we realized that even student labor is not nearly as available as military manpower was in the key-constructing era. When we wished for keys most was when we had the least amount of available imagery. Post-WW II keys were generated from the huge caches of photos accumulated by the end of the war.

We soon learned to take terrestrial photographs along with the aerial ones. We became much more observant at the site, and when all else failed we went back and obtained additional ground truth. We have had to learn to identify most of the local plant communities. Particularly we have had to learn the weeds—those accurate indicators of disturbance. In this, the book Weeds of the West has been especially helpful. A large clump of wild lettuce, for instance, sticks out on 1:330 imagery. Once identified, however, the interpreter does not need a key, just memory.

For the last three years we have been teaching a class in low-altitude/large-scale imagery. The course we teach carries three semester-hours credit. We have a two-hour lecture and a construction lab each week. The instruction is divided into four

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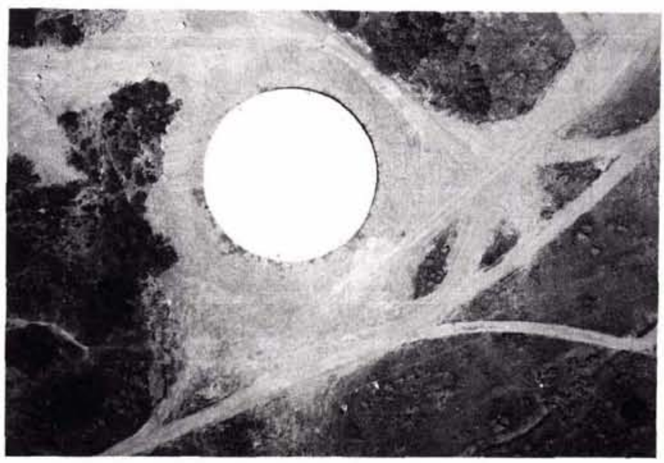

Water storage tank, Pleasant Grove, Utah. Plywood forming in place prior to pouring top of tank.

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parts. Part One covers a short history of low-altitude/large-scale data acquisition design, and system design parameters. Part Two covers as aircraft construction and maintenance in detail. Vibration suppression is covered in theory and practice. Part Three covers mission planning, surveying, and flying. The mathematics of imagery are covered in detail as well as the image motion problem. This section treats plotting, analysis, and image interpretation. The final part covers cameras, film, and processing and printing.

The most important benefit of teaching this class has been the innovative and creative energy fed back into the class by the students. All the frustration of getting a new class through curriculum has more than paid off in the first two classes.

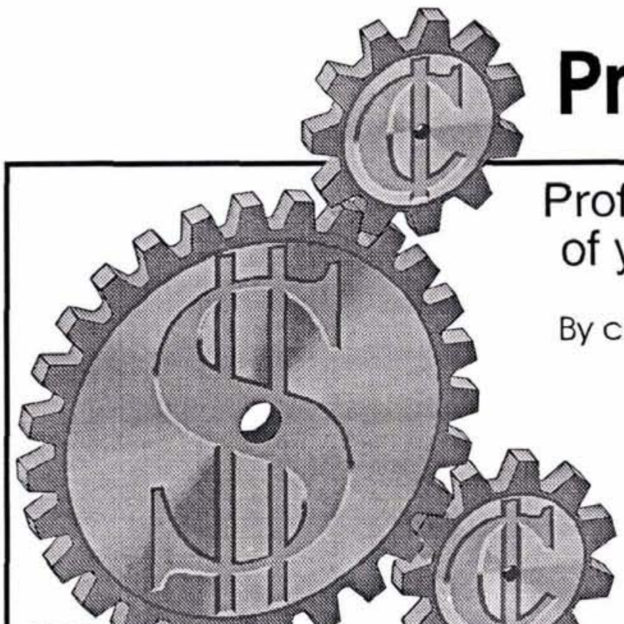
Low-altitude/large-scale reconnaissance has a definite contribution to make in a variety of disciplines where very large-scale imagery with high critical resolution is required. This is not the poor man's approach to remote sensing. It is fortuitous that the system (including plane kit, radio, and camera) costs less than $1000, that the critical resolution is .187 inches, that with enlargement, scales of 1:20 are possible without grain degradation, that the platform can be flown in areas not otherwise accessible to fixed-wing or rotary-wing aircraft, and that this technology can readily and safely be taught to undergraduates. Or is it good planning and hard work?

### Endnotes


Caylor, Jule. 1989. Film, camera, and mission considerations to reduce image motion effects on photos. USDA Forest Service, Nationwide Forestry Applications Program. Salt Lake City, Utah.

Walker, James W. 1992. Low-altitude/large-scale reconnaissance systems. Technical Marketing Society of America. This paper details all the technical data alluded to above.





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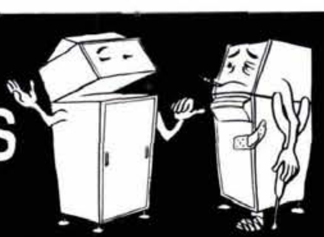

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