Low-Altitude Aerial

LOW-ALTITUDE REMOTE CONTROLLED AIRPLANE

During the fall of 1998 and late summer of 1999 a 35-mm camera was mounted on the underside of a remote controlled airplane and used to photograph the RGDT. Jerry Fiedler of BLM- NSTC, and Randy Claussen constructed the Low-Altitude Remote Controlled Airplane (LARCA). Larry Cunningham, NSTC's Aerial Photography Acquisition Coordinator, documented, and assisted with the testing and refinement of both LARCA and on-board camera systems. Several successful LARCA missions were flown over the "dry wash" and selected outliers.

In 1998 a front engine, Senior Telemaster aircraft was extensively tested at a remote control airplane airstrip located at Chatfield State Park near Denver, Colorado. The plane had a 2.44-meter wingspan and MVVS 1.44, 2-cylinder engine. An Olympus 35-mm Single Lens Reflex (Model OM 2n) camera was mounted, in a container, on the underside and in the middle of the aircraft. The camera was equipped with aperture priority automatic setting or full manual setting, an automatic film advance, and an electronic cable release for the shutter. Several different camera settings, lenses, and film types were tested during this time.

A number of items were considered when choosing and mounting the camera such as:

- The weight, shape, and size (length and width) of the camera.
- The need to avoid radio and electronic interference between the camera's routine operation, the remote operation of the camera, and the remote controls which operated the LARCA.
- The need to isolate the camera from aircraft vibration.
- The ability to remotely activate the camera systems and range limitations for remote activation.
- The cameras ability to automatically advance the film.
- The need to minimize tip and tilt of the camera.
- The need to lock the focus at infinity verses using the auto focus.
- The need to set the shutter speed (should not drop below 1/200 of a second) versus using the auto exposure.
- The need to use manual focusing and a set focal length lens, which usually give better quality pictures, versus zoom and auto focus lens.
- Camera battery life limitations.

A digital camera was considered, however, at the time of the testing digital cameras with the needed pixel resolution were not economically feasible. Another disadvantage was the length of time to store each image would not allow for stereoscopic coverage.

Once a configuration for the plane and the type of camera were established the next procedure was to determine the correct lens focal length and flying height to produce the desired photographic image scale. Scales, which would result from different combinations of lenses and flying heights were calculated using the following formula (Table 1):

scale = height above ground/lens focal length

Table 1. This matrix gives the resulting photograph scale with varying flying heights and lens sizes.

	Lens Focal Length					
	28mm	50mm	135mm	153mm	200mm	305mm
Flight Height	(1.1")	(2.0")	(5.3")	(6.0")	(7.9")	(12.0")
Above Ground	(10.9 ratio)	(6.0 ratio)	(2.26 ratio)	(2.0 ratio)	(1.5 ratio)	(1.0 ratio)
30.5 m (100 ft)	1:1089	1:610	1:226	1:199	1:152	1:100
61.0 m (200 ft)	1:2177	1:1220	1:452	1:452	1:305	1:200
91.4 m (300 ft)	1:3266	1:1828	1:677	1:598	1:457	1:300
121.9 m (400 ft)	1:4354	1:2438	1:903	1:797	1:610	1:400
152.4 m (500 ft)	1:5443	1:3048	1:1129	1:996	1:762	1:500

The LARCA had a maximum altitude of 304.8 m (1000 ft) above ground, but for visual navigation along the flight line, 152.4 m (500 ft) is the highest recommended flying height. A lens length between 50 mm and 135 mm was considered to be best. Shorter lenses (28 mm) would have excessive distortion and would necessitate much lower flying heights. Longer lenses (200 mm to 305 mm) allow for greater-flying heights, which could result in improved aircraft stability. However, longer lens have accompanying drawbacks, such as slower shutter speeds, more payload weight, and physical lengths that may be too long for mounting in a plane. For most of the missions at RGDT a 50-mm focal length lens was used.

The area of ground covered by a frame of 35-mm film taken using the 50-mm focal length lens was then determined for a variety of scales (Table 2). The dimensions of film commonly referred to as 35-mm are actually 24 mm (.95”) x 36 mm (1.4”). To adequately cover the width of the “Ballroom” (14 meters, 45 feet) it was decided that the long dimension (36 mm) of the film should go from side to side and the short dimension (24 mm) should go along the line of flight. A scale of 1:400 would provide adequate coverage of the “Ballroom” with only one flightline while still maintaining adequate resolution. In order to obtain stereoscopic coverage each frame had to overlap the next by 60 percent (Table 2).

Total ground coverage per frame x 40% = Forward gain per exposure

Table 2. This table lists the ground distance, in meters, that is covered by photographs taken using 35-mm format film (24 x 36 mm) and a 50-mm focal length lens.

Flight Height (m) Above Ground	Scale using 50 mm focal length lens	Coverage per frame (m x m)	40 Percent Gain per exposure (m)	Linear Coverage (m) per 36 exp. roll
15.2	1:300	7.2 x 10.8	2.9	103.7
20.0	1:400	9.6 x14.4	3.8	138.2
30.5	1:600	14.4 x 21.6	5.7	206.3
45.7	1:900	21.6 x 32.4	8.7	311.0
61.0	1:1200	28.8 x 43.2	11.6	417.0
76.2	1:1500	36.0 x 54.0	14.4	518.4
91.4	1:1800	43.2 x 64.8	17.3	622.1

Ground distances covered by the LARCA were calculated for a variety of speeds (Table 3).

Table 3. This table provides the distance traveled by the LARCA for a variety of speeds.

km/hr	m/sec
24.1	6.7
32.4	9.0
40.3	11.2
48.6	13.6
56.5	15.8

The distance covered per frame (24 mm) was then combined with the distance traveled by the aircraft used in the following equations.

Forward gain per exposure / aircraft ground speed = exposure timing interval

The timing interval between exposures was calculated for a variety of speeds and scales (Table 4).

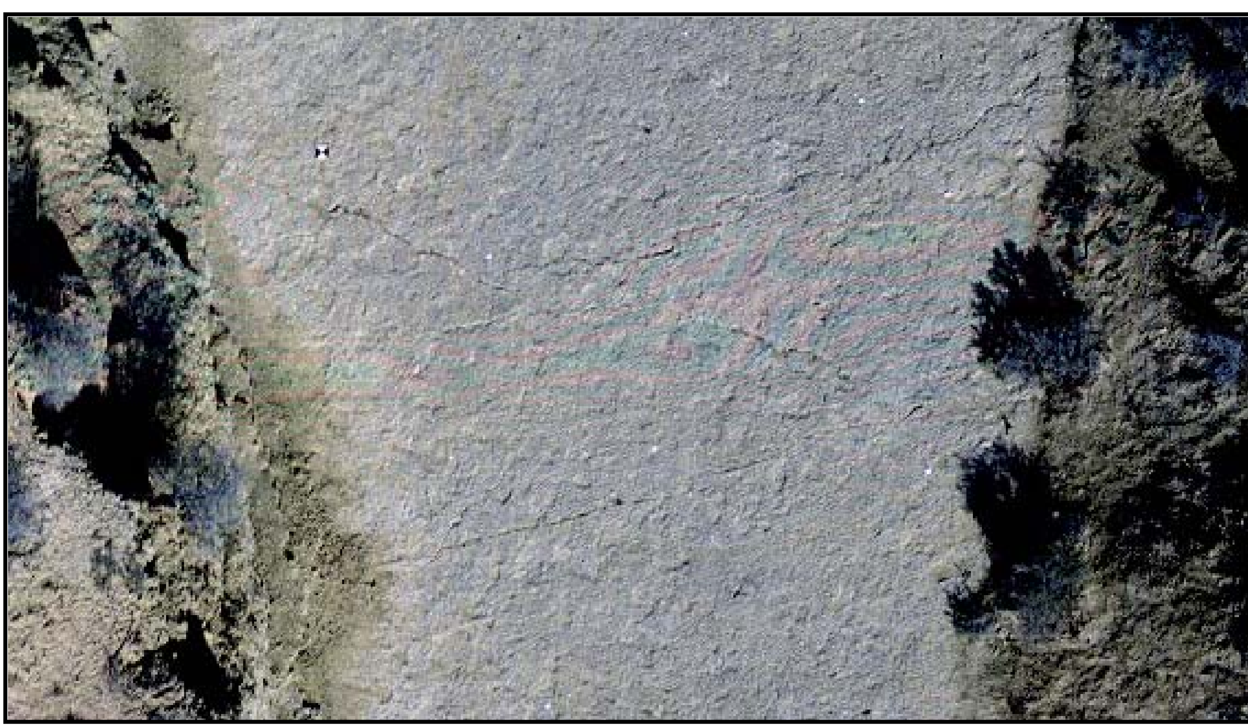
Table 4. Timing interval, in seconds, for varying scales and ground speeds.

	40 Percent Gain	Aircraft Ground Speed				
Scale	per exposure (m)	6.7 m/sec	9.0 m/sec	11.2 m/sec	13.5 m/sec	15.7 m/sec
1:300	2.9	0.43 sec	0.33 sec	0.25 sec	0.21 sec	0.18 sec
1:400	3.8	0.57 sec	0.42 sec	0.34 sec	0.28 sec	0.24 sec
1:600	5.7	0.85 sec	0.64 sec	0.50 sec	0.42 sec	0.36 sec
1:900	8.7	1.29 sec	0.97 sec	0.76 sec	0.64 sec	0.55 sec
1:1200	11.6	1.72 sec	1.31 sec	1.00 sec	0.86 sec	0.74 sec
1:1500	14.4	2.16 sec	1.64sec	1.28 sec	1.08 sec	0.93 sec
1:1800	17.3	2.60 sec	1.95 sec	1.53 sec	1.29 sec	1.11 sec

The shutter speed for these calculations was set at a 1/250 of a second. The speed of the Olympus OM2n auto winder was .4 seconds. Thus to obtain stereoscopic coverage at a scale of 1:400 a ground speed of approximately 32 km/h (20 mph) would achieve the best results. Several test missions were flown at a remote control airplane airfield located at Chatfield State Park, Colorado. Larry Cunningham inspected the photographs taken during these missions for consistency of stereoscopic coverage and other parameters (Appendix I).

After the calculations were finished and testing was completed the LARCA was transported to the RGDT in October of 1998. Eight missions were flown during a 3-day period, seven in natural color and one in black and white. The flyovers were considered a success as the entire "dry wash", as well as, two important outlying areas were photographed. The resulting scale of the photography was very close to those calculated and the desired resolutions were achieved.

Because there was no through the lens viewing alignment of the camera over the target area was done visually from the ground. This resulted in some misalignment of photos but with the number of missions all the areas were covered.



As a result of the October 1998 flyovers several issues surfaced with respect to inefficiencies in the aircraft and camera mounting system. The engine was mounted at the front of the airplane; thus the camera and camera mount got dusty and oily during takeoff and flight, requiring the lens to be cleaned after each mission. There was also limited space for the camera in the housing as heavy foam packing material was used around the camera to minimize vibration from the engine. The camera held a roll of 36 exposures film making frequent takeoffs and landings necessary. This resulted in down time during the unpacking and packing of the camera for film reloading after each mission. Takeoffs and especially landings were themselves problematic due to the two-wheeled configuration of the airplane, the extra weight of the camera, and the gravel parking lot at the RGDT.

To provide more stable takeoffs and landings, and a larger area for mounting the camera, the aerial platform was redesigned. A rear-mounted propulsion, utility styled, 3-wheeled aircraft was chosen. It was equipped with a camera bay built into the body making outside mounting unnecessary. The rear mounted, 32.5 cc, 2-cycle engine combined with a 2.4 meters (96 inch) wingspan provided a much more stable ride. Mission duration was also increased to 120 minutes. A 250-exposure back was purchased for the Olympus OM2n body, thus reducing the frequency of landings and takeoffs. The new platform and camera system were also tested at Chatfield State Park in the summer of 1999. In the late summer of 1999 this LARCA was used for flyovers at the RGDT. Although this aircraft itself performed better, problems with the 250-exposure film back occurred during flight. This necessitated the use of the 36-exposure film back, resulting in limited use of the LARCA at the RGDT.

During both of the flyovers at the RGDT valuable information was learned with regard to the use of the LARCA and camera system. Features of the physical surroundings must be considered, such as, the proximity of appropriate takeoff and landings. Paved surfaces, such as road or parking lots, are optimal. However, in the case of RGDT the nearest paved road was six miles away, necessitating the use of a smooth dirt or gravel surface. The gently rolling hills, low sagebrush, and lack of trees at the site were beneficial for using line of sight to align the aircraft over the target area. The north to northeasterly trend of the “dry wash” provide a good window of time near mid-day when the entire track-bearing surface was virtually shadow free. During both flyovers the weather was optimal with clear blue skies and low wind. Weather could obviously have a great impact on the success of the mission either through precipitation or high winds.

Factors that affect the final quality of the photography were also verified during these missions. Aircraft speed was very important as it both influenced the stereoscopic coverage and image quality. Slow speeds (32 km/h or slower) proved to be better, however a steady flight had to be maintained. Faster speed film (200 ASA or faster) was generally better as it minimized the motion induced image blur. However, slower speed films are finer grained and provide higher resolution, thus a need for balance must be met. Faster shutter speeds also reduced image blur. Keeping the LARCA level was a continuing challenge. Haze or daylight type filters for the lens would be beneficial to produce sharper images and protects the lens. The inability to "see" what the camera is taking a picture of at the time of exposure is probably the single largest draw back to this system. Determining an effective way to control coverage, alignment, stereoscopic overlap, etc. from the ground would be very beneficial.

There are other factors, which affect the success of the mission, that are not directly related to the LARCA or the camera system. The area to be photographed should be cleaned and extraneous material should be removed. Cleaning at the RGDT was accomplished by an enthusiastic group of volunteers who swept the surface with brooms and hosed it off with water from a water truck. Control panels need to be placed on the ground prior to flying the photography. The ground control is used to visually reference known locations where geographic coordinate control exist. In the case of the RGDT select one-meter grid corners were used as control locations and were marked with 6 cm (2.25 inch) white ceramic tiles. As the area covered by each frame is somewhat limited some type of on-the-ground distance reference is useful for determining scale. This can be accomplish by placing reference panels at a pre-determined distance apart or by placing a stadia rod in the image. It is also useful to mark features of interest in some way so that they are easily distinguishable on the photography. During mission planning it is important to factor in additional people to help with the cleaning of the site, the placing of ground control, as well as to assist the aircraft pilot and LARCA support staff.