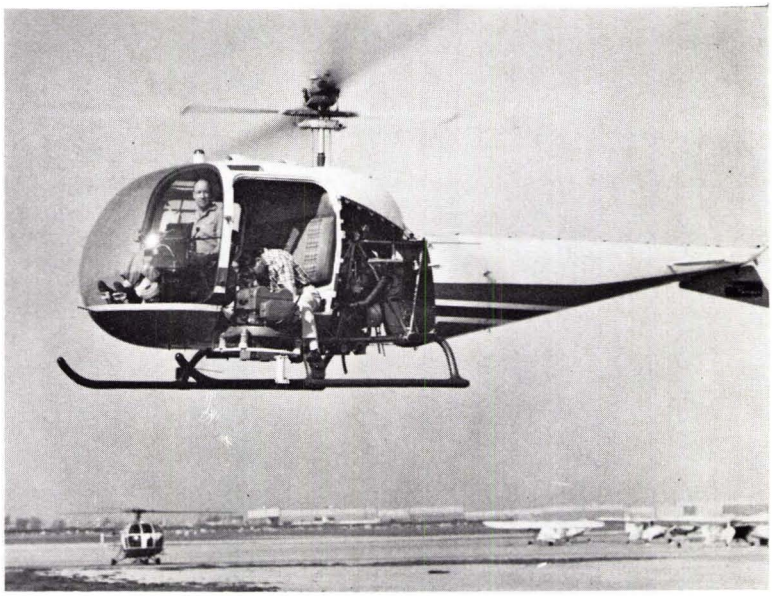

FRONTISPIECE. The helicopter and aerial camera in flight.

F. B. ROBISON
L. I. WITHEM
Pictorial Crafts, Inc.
San Bernardino, Calif.

Helicopter Photography and Mapping

An experiment at an altitude as low as 300 feet had a maximum vertical error of only 0.06 ft.

(*Abstract on next page*)

IN THE FALL OF 1963 our firm began to experiment with large scale photography using a helicopter instead of conventional aircraft. At that time Pictorial Crafts had been providing the aerial photography and related products, such as prints, index maps, diapositives, enlargements, etc., to many of the photogrammetric mapping firms in California for nearly ten years.

During these years the continuing requirement for greater accuracy, particularly vertical accuracy, was accomplished by refinements in both equipment and techniques. In 1953, the year our firm began operations, the cameras and plotters in general use were quite primitive compared to today's equipment. Since that the time distortion-free lenses, polyester film, and plotter refinements have brought photogrammetric mapping into general use by most surveyors and engineers, and exclusive use by many governmental agencies.

However, there continued to be projects where vertical error of even a few tenths could not be tolerated. Places where pavement lap was critical, such as bridge approaches, airport runways, etc. continued to be cross-sectioned by field survey methods. Some attempts were made to use the photogrammetric system for such projects by mounting the aerial camera on a boom. Some of our clients requested flights at 900 feet above the ground and occasionally even 600 feet to permit compilation at larger scales with the resultant increase in vertical accuracy.

The extremely short interval between exposures, shutter speed of the camera, and the danger of flying low and slow in conventional aircraft made this impractical.

Our thought was *how about using a helicopter*? It can fly low and slow *legally*. This had been tried before, but the amplitude of vibration made the photographs so blurred that the idea had been abandoned by most who had tried it. Another objection raised was that the turbulence created by the helicopter blades would cause refraction of the rays entering the camera. The only way we could find out if this technique was so impossible was to try to see for ourselves.

ABSTRACT: *In 1963 Pictorial Crafts, Inc., began experiments and development of a vertical camera mount for use in a helicopter. Some projects require larger-scale photography and mapping. Problems in using the helicopter for mapping photography include: provision of a camera hatch, the* X*-tip and yaw characteristics of a helicopter, control of flight altitude, flight planning to minimize hidden areas, etc. The requirement for accessability and unobstructed view for the camera led to the choice of the Bell J-2 and Wild RC-8 combination coupled with a vibration dampening mount. Test photographs taken at 300 feet above ground proved to be free of blurring due to motion or vibration, and subsequent work performed for several governmental agencies at compilation scales of both 1 inch = 10 feet and 1 inch = 20 feet was highly successful.*

THE NEXT STEP was the choice of a suitable helicopter. Unfortunately, most helicopters have the area under the floor full of control system components, making it impractical to make a suitable camera port through the floor. We made a list of the requirements of a camera mounting system:

- Camera lens must be in position to provide full view without cutoff from landing skids, etc.
- Camera must be accessible to operator for adjustment of level, crab, etc.
- If possible, system should be adaptable to any helicopter of type chosen and should permit mounting with little or no modification to helicopter airframe.
- Since the center of gravity and balance of a helicopter is more critical than conventional aircraft, the helicopter must be large enough to carry camera (200-plus pounds), crew, and ballast to offset camera weight.

These requirements narrowed our choice of a suitable helicopter to the Bell J-2. This particular machine has a removable section of floor on the left side designed for a hoist rig, and as it happens, was large enough to permit placing our camera in an almost ideal position, fulfilling the first two requirements above. Also, the Bell J series is in wide use all over the world.

OUR CAMERA, A Wild RC-8, was well suited for the system. The proximity of the camera controls and the attachment of the viewfinder telescope to the camera proper seemed to have advantages.

Mercury General American of Torrance, California, operates a helicopter service including Bell J-2 models. James Gavin and Robert Berliner, who manage the company, were very cooperative when we approached them with our idea. George Hewlett, chief mechanic for the company, spent many hours with us helping with the design of a suitable mount, and he ultimately made our prototype mount.

The mount consists of a frame attached to the landing skid and to the floor of the helicopter using the seat widgets exposed when the seats are removed (Figure 1). The camera is attached to the frame through the vibration-dampening mounts, which are designed to let the camera *float* and to let the airframe vibrate around it. The camera control box is attached on the floor inside along with the electrical connections and a vacuum pump (Figure 2). The photographer site is within easy reach of the camera controls. The mount is designed so that it can be attached to any Bell J-2 and be ready to fly in about 30 minutes. Ballast necessary to balance the helicopter is placed on the opposite skid and in the tail section.

OUR INITIAL TEST of the equipment was on March 30, 1964. The weather was very uncooperative, and the first pictures were taken at

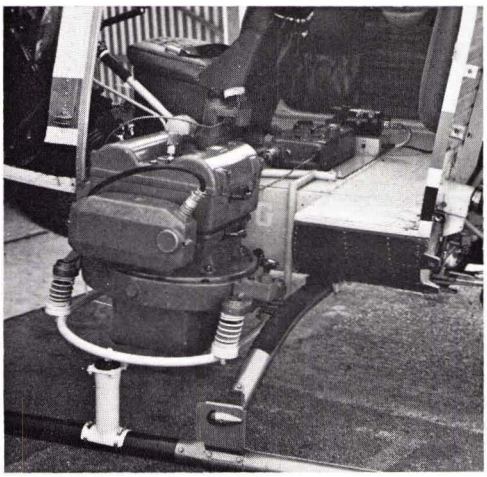

FIG. 1. The aerial camera is mounted outside the cabin using special vibration-damping fixtures.

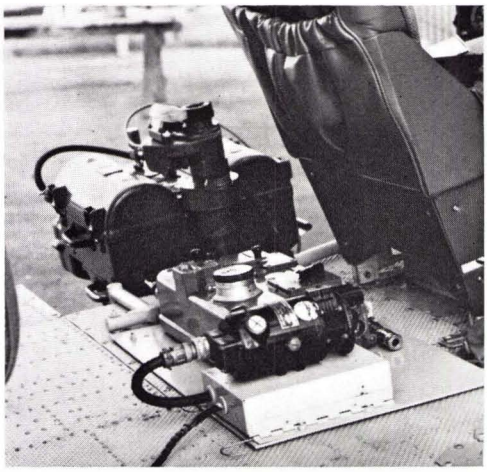

FIG. 2. The camera control box and vacuum pump are located on the floor inside the cabin.

4:30 P.M. under overcast skies—somewhat less than optimum conditions. We planned on shooting a strip of pictures with the usual 60 per cent overlap both 900 feet and 600 feet altitudes. This done, we could not resist the temptation to shoot a strip at 300 feet elevation as well. The flying speed was just under 25 mph.

The resultant negatives were examined for sharpness; diapositives and 5-diameter enlargements were made and examined of the 1-inch = 50-feet photography. The enlargements were very sharp and showed no evidence of vibration transmitted to the camera. The dispositives were set up in a plotter and the results showed the potential of a very high degree of vertical accuracy.

THE NEXT STEP was to obtain engineering for the mount apparatus and approval of the apparatus by the Federal Aviation Agency. The engineering department at Bell Helicopter Co. in Ft. Worth, especially Mr. Anastasi, Mr. Schroeder, and Mr. Rollings, were very helpful in releasing information about the flight characteristics and associated data for the Bell J-2 series helicopter. With this information, flight tests, weight and balance tests, and the usual mountain of paper work resulted in our obtaining a supplemental type certificate for our mount. This permits us use of these mounts and authorization to manufacture them. Patents were applied for on both method and apparatus in March, 1965.

A number of projects have been completed in the last $2\frac{1}{2}$ years using this technique. Mapping at a compilation scale of 1 inch = 10 feet has been done for the City of Los Angeles, County of Los Angeles, and the California State Division of Highways. Test results from the Photogrammetry Section of the Division of Highways are shown in Tables 1 and 2. Note the maximum error of .06 foot out of 80 points tested on hard surface roadway in Table 2.

OUR EFFORTS HAVE not always gone unnoticed. Curious residents have called in to

TABLE 1. STATISTICAL ANALYSIS OF PHOTOGRAMMETRIC MAPPING

San Diego—Coronado Crossing Scale 1″ = 20′ A.S.C. 1275

Surface Type	*Contours*			*Spot Elevations*		
	No. of Points	*Arithmetic Mean*	*Standard Error*	*No. of Points*	*Arithmetic Mean*	*Standard Error*
Bitum	43	+.027	±.162	63	+.055	±.084
PCC	21	+.050	±.143	8	−.006	±.116
Dirt	87	−.033	±.245	48	+.009	±.111
Grass	22	−.034	±.149	59	+.001	±.094

TABLE 2. STATISTICAL ANALYSIS OF PHOTOGRAMMETRIC MAPPING

Hollywood Fwy. Scale 1″ = 10′ A.S.C. 1428

Error in Feet	*Number of Points*		*Algebraic*		*Numerical*	
	+	−	+	−		
0	11					
.01	9	7	.02		16	.0016
.02	12	9	.06		21	.0084
.03	14	4	.30		18	.0162
.04	9	0	.36		9	.0144
.05	3	1	.10		4	.0100
.06	0	1		.06	1	.0036
Total	+.84		−.06		Total	.0542

Arith. Mean $\frac{0.78}{80} = \boxed{+0.01}$ Std. Error $\sqrt{\frac{.0542}{80} - 0.0001}$ $\boxed{\pm 0.024}$

ask what was going on. On enlargements of the photographs most people visible are shading their eyes and gazing up at us. We were "run in" once by the sheriff's helicopter. We were released after the deputy found out "just what in the world we were doing."

Compilation of maps at either 1 inch = 20 feet or 1 inch = 10 feet is quite spectacular to the plotter operator. Not only is the vertical perception and accuracy increased, but valves, manholes, water meters, pole transformers, (occasionally sunbathers), etc. are visible. On occasion, $1\frac{1}{4}$-inch shiners were used as premarks and every one was visible.

The technique of taking the photography is considerably more difficult than at smaller scales from conventional aircraft. A helicopter is more subject to yaw motion as well as to X-tip than conventional aircraft. The arrangement of the Wild RC-8 camera with the viewfinder moving with the camera proper is not only handy but necessary to make quick corrections for crab and tilt. Differences of as little as 10 feet in altitude between exposures make orientation in the plotter difficult and must be avoided as much as possible. The *leaning* of tall structures over sidewalks and streets may have to be accounted for in job planning.

As the camera mount is designed specifically for use with the Wild RC-8, agreement has been reached recently with the Wild-Heerbrugg Co. to distribute these mounts for us.

We believe that this technique will come into wide use in the near future.