tem. Miniaturizing the camera provides a greater problem from the control and steadiness point of view. One might think it would be easier to control the smaller camera; actually it is more difficult.

MR. HARMON AVERA (Naval Photographic Interpretation Center): One slide indicated that the automatic mounts to weigh less than your manual mount. Is that for the mount itself or for the mount with the electronic control?

MR. PALLME: The mount itself will not weigh less. But the system weighs less. Take out an operator and you have a lower weight system.

MR. JAMES WEBB (Army Map Service): Considerable progress has been made in obtaining a relative verticality with stabilized mounts. However, in the past there have been problems due to inertia and acceleration forces building up in the system. We have had difficulty in obtaining absolute stabilization. Has any marked progress been made in that field?

MR. PALLME: Very definitely, marked progress. The general concept of stabilization has been changed through the efforts of the Wright Air Development Center, in the direction of the use of torquer mounts, where the effect of inertia can actually work for you instead of against you.

In the A-28 mount, one of the early approaches to mounting, a fairly good control of verticality is obtained. But rapid motion has presented the problems you indicate. Presently, with the torquer mount, this is no longer a problem. Aircraft can move at any rate or any acceleration that they can develop, and the mount is not affected, because there is no gear drive that must be accelerated. Actually, the camera is trying to stand still in space.

LT. HOLMES (U. S. Coast & Geodetic Survey): How do users of automatic mounts that have eliminated the operator accomplish the changes of the magazines when more than one roll during the flight is to be exposed?

MR. PALLME: So far as my experience goes, they probably do not accomplish that. There is certainly a possibility for setting up methods of doing it. Or larger rolls of film could be used.

MR. LAYLANDER (Photogeologist): I do photographic work, and change magazines in flight. It's not very difficult if you have your camera where you can reach it.

The Role of the Airplane in Aerial Photography

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ABSTRACT: *The basic requirements of an aerial negative in engineering photography are discussed. The effect of image motion on detail and the relation of aircraft design and operation to image motion, both for large and small scale photography are described. The relationship of airplane productivity to photography cost is pointed out along with individual problems in aircraft available to commercial operators. Also discussed are the problems of crew efficiency and safety and how they are connected with the quality of photography.*

EACH year we attend this convention to exchange ideas and to learn the progress made during the year by the many engineers and authorities in the field of photogrammetry. Personally, I come away excited by new potentialites and eager to put them into operation. Then I return to my office—only to face cold, hard reality!

Much of the new equipment is not actually available, or is not economically feasible. For instance, I know that many of our problems could be solved if we could purchase new aircraft specifically designed for our purpose. Since no "mapping" company could afford to support such a program, we must all continue to modify, remake, and make-do.

In obtaining aerial photography the airplane is basically a platform for a camera. It is a tool which, properly used, will enable us to produce high quality negatives for photogrammetic use. For our purposes, an airplane must have the range, performance, and equipment facility to produce this photography within sound economic limits. In private industry we are always faced with a compromise between the quality that it might be possible to obtain, and the economics of production.

To a great extent the costs of producing engineering photography may be directly related to the design and operation of the aircraft used. A similar relationship exists between the design and operation of the airplane and the quality of the negatives obtained.

I am quite certain that in too many cases, the aircraft used is chosen solely on the basis of economy of operation and ease of flying, rather than its suitability as a camera platform. If the quality desired by the photogrammetrist were the sole basis for all our planning, a lot of the airplanes used to produce aerial photography today would be grounded.

If we assume that the quality negative is our primary goal, we must consider three variables which contribute to the end result:

First, we shoot through miles of atmosphere, and hence are faced with atmospheric obstructions and changing air density, the result is diffusion of the incident light. In order that the greatest possible production may be made during clear weather periods, the airplane should have the highest possible performance, that is, a high rate of climb and a maximum permissible cruising air speed. To meet production schedules, a low performance airplane means long working hours, which crowd the solar altitude, and working on days when atmospheric conditions are questionable.

Second, we are shooting from a moving platform. This movement results in image motion on the aerial negative. If the magnitude of this motion during the exposure interval is great enough to cause visual displacement of the images, they will appear fused together and identification of small detail becomes questionable. Image motion resolves itself into three components: lineal motion due to the speed of the aircraft along its path of flight; radial motion due to swing of the camera unit about a point somewhere along its vertical axis; and tangential motion due to rotation of the camera unit about its vertical axis.

Lineal image motion is proportional to the scale of the negative. It is not a problem in small-scale photography. However, it is a serious limitation in large-scale work; to keep it at a minimum, the airplane must be capable of stable flight at speeds as low as 100 miles per hour; this limits production seriously. Faster film would enable us to use faster shutter speeds, and we would then be able to increase low altitude air speed proportionately. *Radial* and *tangential motions* are not proportional to scale. The airplane must, therefore, have the greatest possible aerodynamic stability for all altitudes in order to keep roll, pitch, and yaw within limits that will enable the photographer—or camera mount servos—to correct for these motions.

Third, our camera platform involves the use of airplanes powered by internal combustion engines and propellers. This results in vibration and possibly heat-smoke contamination of the area through which the incident light must pass. Furthermore, the displacement of the air through which the airplane passes, causes non-uniform air density in the boundary layers surrounding the camera well.

The best way to keep contaminated and disturbed air from under the camera well is to locate the camera in the fuselage away from behind the propeller and engine; this dictates the use of either multi-engine or pusher driven aircraft.

The vibration level in the airplane should be sufficiently low that the camera mount may be attached directly to the aircraft structure without danger of mechanical damage to delicate parts, such as lamps, motor bearings, etc.

Unless the camera unit is mounted at its exact center of gravity, objectionable torque forces of high magnitude, low frequency may be transmitted from the structure to the mount, *via* protective rubber mounts, resulting in angular and rotational movement of the camera unit.

Once we establish that the airplane has a suitable location for the camera and related equipment, as well as aerodynamic qualities consistent with the speed and altitude range intended, we face the question of *crew facility*. In large-scale, low-altitude photography, the crew will usually consist of two men. In this case, the pilot assumes the role of both pilot and navigator. In order that he may properly carry out both functions, the airplane must be easy to fly, and stable enough to maintain its heading and altitude during the periods when the pilot must study his chart. The aircraft should be so constructed that adequate forward visibility from the pilot's seat is afforded, enabling the pilot to maintain course by reference to the ground ahead of him. For reasons that I hope I have already made clear, I do not believe that the use of single-engine airplanes is ever appropriate for this type of work. In single-engine aircraft the camera will always be behind the engine!

In small-scale, high-altitude photography, the use of single-engine aircraft has rarely been attempted, since they are too small to carry the additional radio, instrumentation, and other facilities required where the scope of areas involved is so much greater. On the basis of our experience in high altitude photography, we feel that the airplane should be capable also of carrying a *three-man crew*, consisting of pilot, navigator, and cameraman. Furthermore, we believe that the cabin should be *pressurized* to at least two pounds per square inch.

We have been discussing the role of the airplane in obtaining aerial photography, but it is not possible to separate the airplane from the skills of the men who produce the end results. The best aerial surveying airplane is no better than the men who use it!

Our experience has shown that efficiency and skill of crewmen drops sharply when they are working at 30,000 feet or above. I believe there are two main reasons for this: at high altitudes the airplane becomes much more difficult to operate, and the equipment is necessarily more complex. The airplane must have turbo supercharging, additional fuel tanks, fuel pumps, warning systems, etc. The airplane has less aerodynamic stability above 30,000 feet due to the loss of control pressures. Visibility from within the airplane is also reduced by the higher nose altitude, and the horizon tends to merge into atmospheric haze. All these things add greatly to the burden of the pilot.

The photographer must cope with a much smaller scale on his tracking instruments, and his concentration must be much greater in order to measure exact distances on the ground. Since the flying at high altitudes is less stable, even the leveling of his camera unit involves more activity.

By distributing this work-load among three men, the degree of accuracy attained is much greater. The reduction of fatigue makes possible longer flights to take advantage of clear weather, and fewer good days are lost due to illness among crewmen.

Other factors which increase fatigueability and thereby decrease production, include anoxia, "bends," and extremely low temperatures—which at 36,000 feet may be from 70 to 80 degrees below zero. The only logical solution to these problems is to pressurize the working area of the airplane—thus eliminating both anoxia and "bends," and minimizing the very real fear of oxygen equipment failure! It's a long way down from seven miles up—I've worked up there and I know!

Admittedly, pressurization of aircraft is very expensive, and the addition of one man to the crew increases labor costs by 33%. These costs must be carried by the buyer and user of the photography. More uniform production schedules and closer adherence to specifications are obviously an advantage to the purchaser. Better quality negatives reduce his costs in using the product. The supplier of engineering photography cannot justify increasing his costs by using multi-engine aircraft, three-man crews, nor invest in the pressurization of his equipment unless this fact is recognized by the agencies which contract for aerial photography. So long as contract specifications do not require the use of proper equipment and methods, the general quality of the negatives supplied will not be improved.

Discussion of Mr. Miller's Paper

MR. HARMAN: Are there any comments or questions from the panel? If not, we have a few minutes for questions.

MR. VICTOR ELLIS: I am from Montclair, New Jersey and am a retired commercial photographer who knows very little about aerial photography. Would it not pay our Government to produce just one airplane of the type described by Mr. Miller?

MR. MILLER: Our Government, at least within the military corps, has produced a great many. However, in commercial mapping, we can't always take advantage of what's been produced through the military.

MR. REVERE SANDERS (Aeroflex Corp.): Some years ago Ted Abrams designed and constructed an airplane that was primarily designed for use in aerial photography. I'm sure that he was disappointed that no one seemed much interested in an airplane designed strictly for aerial photography.

MR. MILLER: Mr. Abrams for many years has been ahead of others in some aspects of mapping and photogrammetry, as we are all aware. His airplane was developed as a visionary venture, probably long before cameras, lenses, films, specifications and general mapping techniques evidenced the need for better negatives; and definitely prior to the time that photogrammetrists and their photogrammetric equipment were capable of utilizing better negatives. All of us in actual field operation regard with much reverence the airplane he developed, because it was very nearly the ideal design.

*The Influence of Atmospheric Haze on the Quality of Aerial Photographs**

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ABSTRACT: *An ideal aerial photograph is one in which the brightness and dimensional relationships of terrestrial details are reproduced without degradation or distortion. The problems involved in achieving this objective are numerous, not the least of which is that introduced by atmospheric haze. The visibility of an object is related to the brightness contrast between the object and its background, its size, structure, and the spatial gradients at its boundaries. The magnitude of the brightness ratio at the limit of visibility depends upon all of these factors. The superimposed brightness of the atmosphere, by increasing the brightness level without affecting the brightness differences, reduces the ratio, and hence, the visibility. Various methods for improving the visibility of details in aerial photographs are suggested by tone-reproduction theory.*

ATMOSPHERIC haze is as variable and, in many respects, is less predictable than the weather. Like the weather, much is said about it, but unlike the weather, something can be done about it, photographically speaking. Although there is much more to be learned about the nature of the phenomenon that gives rise to haze in the atmosphere, present knowledge provides a basis for practical measures by which the loss in contrast attributable to atmospheric haze can be effectively minimized. An obvious practical solution to the problem is to increase the gamma of the negative material, or to make the prints on a harder grade of paper whenever the photographs are taken on a hazy day. This straightforward measure has

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