THE USES OF HIGH ALTITUDE PHOTOGRAPHY FOR MAPPING AND RECONNAISSANCE*

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INTRODUCTION

IN ASKING me to prepare this paper, Mr. Eliel explained that it should serve as the lead paper for the panel discussion on High Altitude Photography. This implies that the paper should cover all aspects of the subject, in order to lay a good foundation for this afternoon's discussion. But I wish to make clear that what I will say here will not constitute a full coverage. The limited time I had available to prepare this paper did not permit assembly of all the information which I found that I was lacking. In addition, I am wholly unqualified concerning the operation of airplanes, and what I say here concerning flying matters is merely repetition of the few comments I have heard from more qualified sources. I hope that the members of the panel this afternoon can make up for these deficiencies of mine, and broaden the coverage of the subject for those of you who are interested.

After some thought on the subject of illustrations for this talk, I decided against preparing any. Any appropriate illustrations would have involved aerial photographs and I feared that lantern slides would not do them justice. Instead, I have arranged for appropriate material to be included in the exhibit of the Army Map Service, and those interested are referred to that exhibit to determine for yourselves what you can see on photographs taken from 35,000 to 40,000 feet in the air.

At the outset, I find it necessary to define what constitutes high altitude photography, and to clarify whether it is altitude above sea level, or above terrain level that I am talking about. With reference to problems concerning the flying of photography, the altitudes I shall refer to will be based on a sea level datum. With reference to the resulting photography or its use, I shall employ the term "flying height," this height being measured above the mean terrain level as a datum. Now what constitutes a high altitude? I have selected 25,000 ft. as the approximate dividing line. It is at about this altitude that the newer problems seem to arise and more difficulty has been encountered in procurement of photography. Of course, it should be noted that this is not a fixed situation, and what I call high altitude today will probably be considered as not so high in another five or ten years.

I also find it necessary to define mapping and reconnaissance photography for the purpose of this paper. I define the former as that photography required for compilation of planimetric or topographic maps or charts, regardless of desired map or chart scale, and regardless of the accuracy desired in the map or chart, provided the desired end product is to be something more than just a pictorial representation of the terrain. In spite of Webster's defining "reconnaissance" as "a survey," I have adopted what I believe to be a definition that is more in accord with recent usage as applied to aerial photography. For the purpose of this paper, I regard reconnaissance photography as including only that

* Paper read at the Sixteenth Annual Meeting of the Society, Washington, D. C., January 13, 1950.

NOTE: Comments on this paper are invited. To ensure consideration for publication in the September issue, receipt before July 15 is necessary.

photography intended primarily for qualitative study; for example, photography for military intelligence, for forestry typing, for geologic interpretation, etc.

WHY PHOTOGRAPHY FROM HIGH ALTITUDES?

The definitions now being complete, I should like to examine next why anyone would want photography flown at great flying heights. For mapping photography, the basic reason is, of course, a matter of costs. We all know that the cost per square mile of photography goes down as the altitude goes up, and that it also costs less to map a given unit of area with higher altitude photography. It is only logical, therefore, that we fly our photography at the maximum height that still permits meeting the mapping requirement. Those engaged in topographic mapping by stereoscopic methods know that the principal limiting consideration is the "C" factor of the system being employed. As this factor limits flying heights, much effort has been exerted to increase it so that the economies of greater heights may be realized. Some mapping systems already employ a "C" factor of 1,000 to 1,200, and other systems are striving to achieve this. Still further development may increase this factor more. Couple a "C" factor of 1,000 with a contour interval requirement of 25 ft. or more, and you are immediately in the high altitude field. You will also be involved in high altitudes if you couple a "C" factor of 1,000 with a contour interval of 20 feet, if the terrain elevation is 5,000 feet or above. And it is not at all difficult to find examples that will send desired flying altitudes far into the stratosphere. Take for instance those areas of the Rocky Mountain region which require a contour interval of 40 feet as a minimum and which have a mean terrain elevation of 5,000 feet or more. Even with a "C" factor of about 700, which would probably be appropriate for Multiplex mapping in this case, we find ourselves in a position of wondering who we can get to fly our pictures at an altitude of 33,000 ft. above sea level. Other mapping requirements arise where we find altitudes of 40,000 or 50,000 feet, and even higher, being desirable solely from "C" factor and terrain elevation considerations.

This "C" factor is only a convenient expression to relate flying height to the elevation accuracy to be achieved in the mapping. If we examine accuracy requirements for showing horizontal positions in our mapping, we find that we usually have considerably more tolerance in the horizontal direction than we do in elevation. Thus to meet the horizontal accuracy requirement, we can use photography from even greater heights. Should the requirement be only for planimetric mapping, then such photography will be desired. It can also be shown that more economical mapping sometimes results when two sets of photographs are used for topographic mapping; one set from a greater height for aerial triangulation to establish supplementary horizontal control, and the other set from a lesser height for the detail compilation and contouring. To illustrate the altitudes that this horizontal consideration leads to, I believe I need only to point out that horizontal accuracy requirements for 1:24,000 or 1:25,000 scale maps can be met using photography from a flying height of about 30,000 feet with present Multiplex methods.

The examples I have stated thus far have been intended to show that high altitudes are involved even in large scale mapping. It should now be obvious that higher altitudes are even more desirable for the medium or small scales, or for some special purposes such as low accuracy mapping, preparation of flight maps in remote areas, etc.

It may occur to some of you at this point that the desirability of high altitude photography can be offset by the employment of wider coverage aerial cameras, including multiple-lens cameras and multiple-camera installations. I do not believe that this will generally be the case. The merits of such cameras will be present also at high altitudes, and the same considerations I have outlined will still indicate the desirability of high altitudes. In fact, in some cases the advantages of a wider coverage camera are such as to make even higher altitudes desirable.

In the case of military mapping under war time conditions, the considerations I have already outlined will be operative in indicating the desirability of high altitude photography. In addition, the higher altitudes for photographic airplanes make recognition and interception more difficult for the enemy. In fact, it is likely that this will be the controlling consideration in any future conflict, and our photographic aircraft may be forced to altitudes higher than are desirable for the mapping requirements.

In the case of reconnaissance photography, the desirability of high altitudes stems entirely from a consideration of economy of coverage for peace time usage, and coverage plus operational security for military reconnaissance. For general reconnaissance of large areas, it is of course desirable to reduce the flying operation to a minimum, and thus the advantage of increased coverage from higher altitudes becomes apparent. This same principle also applies to smaller areas where the need is for specialized information from the photography, although it may be found on any particular small area that economy of coverage actually results from a lower altitude since the capital outlay for equipment for high altitude work must usually be amortized over a large area.

WHAT ARE THE HIGH ALTITUDE FLYING PROBLEMS?

Now that I have indicated the reasons why users of aerial photography are interested in procuring high altitude photography, I should like to point out some of the problems encountered in flying this photography. The first problem is to get an airplane that will carry the photographer with his camera to the desired altitude. In spite of what we read in the news from time to time, this is no easy task. There are not many airplanes available that can meet the requirement and those that can are largely a result of military development. The airplane must not only get to altitude, but it must get there reasonably fast and have sufficient speed and range left at altitude to make good use of the photographic light and weather available. The assembly of the necessary air frame, power plants, and related mechanical accessories to meet these requirements results in an airplane that is in a different class from those previously used for photography; and the operation and maintenance of this airplane is entirely different. Tremendous and more complicated power plants are required which in turn require more maintenance. Super-chargers are required to overcome the effects of the rarefied atmosphere. And the high altitudes do peculiar things to electric and hydraulic systems, all requiring more care and maintenance.

After we get an airplane to go to the desired altitude, what about the personnel to operate it and the photographic equipment it carries? We all know that oxygen is a must for such personnel. But there is more to it than just thin air, the oxygen content of which has to be supplemented to sustain life. The air pressure is extremely low and the "bends" are not unusual for personnel operating in such low pressures. And with the low pressures comes low temperatures, down to 50 and 75 degrees below zero Fahrenheit. The solution to these problems might seem obvious; that is, pressurized compartments for personnel and heating. But these add more mechanical features to the airplane requiring more power and gas to carry on the work and more maintenance. And they still don't solve the emergency requirement when the personnel may have to leave their plane "via the silk." How do they get oxygen and heat then during the time it takes them to get back within the life supporting environment of the earth, a time sufficient to snuff or freeze out life? The personnel problem at high altitudes is a major one and must be solved simultaneously with the airplane problem, since the provisions for personnel comfort and safety involve still additional equipment.

The photographic equipment problem is not much aggravated by conditions at high altitudes but can not be neglected. The low temperatures encountered give rise to the principal problems, and aerial cameras must be either suitably heated or so constructed that their operation is not affected by the low temperature. Similarly, the effect of low temperatures and low humidities on aerial film must be reckoned with.

With respect to photographic weather, no great change is encountered due to the higher altitudes. However, it should be noted that somewhat less weather can be expected at the higher altitudes due to cirrus clouds. These clouds, which form in the altitude range of 28,000 to 32,000 feet, prevent photography being taken above them while ordinarily having no effect on photography taken at levels below them.

Difficulties encountered in flight line navigation at high altitudes stem principally from the use of fighter-type aircraft for such work. Aircraft of this type have been the most readily adaptable type to date for high altitude work in spite of the fact that pilot visibility is poor, thus leading to difficulties in observation and navigation. One additional factor which has been reported is the high wind velocity encountered, together with fairly rapid changes in its direction. This condition has required more attention to drift corrections. Aside from these, flight line navigation and camera work along these lines is not much different from that at lower altitudes. Although it should be evident that navigation check points become more difficult to recognize at higher altitudes, it should be noted that more navigation tolerance in terms of miles on the ground largely offsets this disadvantage.

WHAT ARE THE PROBLEMS IN USING HIGH ALTITUDE PHOTOGRAPHY?

What are the problems encountered in using high altitude photography in mapping? I believe that I would list earth curvature as the number one problem. Earth curvature has been of concern to us in the past only when performing aerial triangulation. Beginning with a flying height of about 25,000 feet, earth curvature becomes a measurable quantity in the single stereoscopic overlap and due allowance must be made for it. With high altitude photography, earth curvature can also have its effect on horizontal positions, and hence more care must be given to the choice of a map projection to use for its compilation. Aerial triangulation is quite likely to be carried great distances with such photography to establish horizontal positions. In so doing we are really attempting to "flatten out" huge segments of the earth's curved surface. As these segments may have maximum dimensions exceeding 100 miles, we can not overlook the effect of curvature on horizontal positions and the relationship to map projections.

The other problem in the use of high altitude photography for mapping concerns the identification of detail on the photographs that should be symbolized on the map. In view of the definition I have used for reconnaissance photography, this problem also exists for it, although it is the only problem in its use. Experience to date indicates that photographic quality can be obtained at high altitudes equivalent to that obtained at the lower altitudes. Thus the problem of identification resolves itself principally to a matter of scale. Optimum scales for identification purposes will vary with the terrain involved, the mapping requirement, the identification requirement in the case of reconnaissance photography, and what opportunity exists for supplementary identification work on the ground. The solution for the problem of identification is already provided, since longer focal length cameras can be used to provide most larger scales desired. These longer focal lengths may be used separately in the case of reconnaissance work, or be used to supplement the usual smaller scale mapping photography. Multiple camera installations can be arranged so that, with only one flying, an area may be covered with mapping photography as well as the optimum scale photography for the identification problem at hand.

WHAT ARE THE ACCOMPLISHMENTS TO DATE?

I should like to tell you about what aerial photography at high altitudes has been done to date, in so far as I am familiar with it and have been able to assemble data concerning it. I believe that any high altitude work prior to World War II was minor if done at all. There were possibly a few photographic airplanes which could get up to 25,000 feet, but it is doubted that any extensive photography was done at that altitude and probably none above it. With the start of the war, practically all aerial photography, other than military, was suspended; so we must look to the military accomplishments during that period. Many new military aircraft were well advanced in design and testing at the start of the war, and it was not long until they were in production. It was not much longer until camera installations were made in some of these new planes, and we started to see photography move up in altitude. The planes principally involved at this stage were the B-25, the B-17, and the P-38. These were later followed by the B-24 and the B-29. Paralleling this in England, the RAF equipped Spitfires and Mosquitoes for photography. The P-38 and the Mosquito were used almost exclusively in Europe for mapping photography, while the P-38, the B-24 and B-29 were the principal mapping airplanes in the Pacific. In Europe, the mapping photography was not flown at extremely high altitudes. Most of it fell in the range of 25 to 30,000 feet with most of it nearer 25,000. Extensive areas were thus covered, some being flown in a planned attempt to procure a systematic cover, and others giving the appearance of a rather hit or miss method of flying. Although I had seen P-38 test photography from 35,000 feet as early as 1941, and although I expect the Mosquito could have equalled this, very little mapping photography was flown in Europe over 30,000 feet.

In the early days of the war in the Pacific, flying for mapping from high altitudes was performed with the P-38 and B-24 and quite extensive cover was secured. The flight altitude for most of this early work was in the order of 30,000 feet or slightly higher. During these early phases of the island-hopping operations, the mapping cover was not flown in a very systematic manner, and the resulting cover gave a rather hit or miss appearance. With the appearance of the B-29 in the Pacific, photography up to 35,000 feet was secured, although the bulk of the photography taken from these airplanes was still in the vicinity of 30,000 feet. Much of the cover secured was the result of reconnaissance type missions, although considerable areas of the Japanese home islands were photographed in a planned and systematic manner.

Subsequent to World War II, the military services have placed considerable emphasis on further development of aircraft for high altitudes. I'm sure that photography from such altitudes is being considered. Just how high they can now go, I don't know, and probably would not be permitted to say even if I did. However, the military has done very little operational mapping photography at high altitudes. The Air Force has accomplished one project for the Army Map Service involving 1,300 sq. mi. which was flown with a B-17 at 26,700 feet above sea level. The Air Force has also photographed some 36,000 sq. mi. of a high altitude test project for the Army Map Service, from an altitude of 40,000 feet above sea level utilizing P-80s for the work.

Probably the largest amount of high altitude aerial mapping photography to be done to date is that currently under way by commercial contractors for the Army Map Service. A total of 170,000 sq. mi. has been contracted for flying at an altitude of 36,000 feet, and some 95,000 sq. mi. have been completed to date. A B-17 and P-38s have been used on this work. In addition, 148,000 sq. mi. have been contracted for a flight altitude of 30,000 feet, and some 10,000 sq. mi. of this work have been completed thus far. A Neptune PV-1 is being used on this project.

Commercial contractors have also flown a number of projects for the Geological Survey at flight altitudes above 25,000 feet. These projects all resulted from the elevation of the terrain involved since the maximum flight height used was about 24,000 feet. A total of some 22,000 sq. mi. of high altitude photography has been accomplished to date for the Geological Survey, most of it being in the range of 25,000 to 30,000 feet above sea level. Two projects exceeded this range, however, one being flown at 32,600 feet and the other at 33,600 feet.

In connection with a topographic mapping contract for the Army Map Service, one commercial operator is known to have flown two projects at a high altitude in 1946. The two projects totaled approximately 6,000 sq. mi. and were flown with P-38s at an altitude of 35,000 feet. The flying height in both cases was approximately 30,000 feet. I believe this is probably the only case to date of high altitude work by a commercial operator for his own mapping work.

Outside of the work performed from wartime operational photography, I believe that very little mapping has thus far been performed from photography exposed at high flying heights. Many in this audience worked on the wartime projects, and although extensive areas were thus mapped, I am sure that none of us would want to make great claims for the quality of the resulting product. We gained considerable experience from the use of small scale photography and we saw the application of larger scale photographs in conjunction with the mapping. But as for the results, let us just say that we did the best we could with the materials available.

Aside from the war-time mapping, I know of only three operational mapping projects performed to date from photography exposed at great flying heights. Two of these are the ones referred to previously as having been flown by a commercial operator at a flight height of 30,000 feet. Maps at a scale of 1:25,000 carrying a contour interval of 25 feet were compiled from this photography using the Stereoplanigraph and model A-5 Autograph. These maps conform to the national standards of map accuracy and extensive field checks confirm this. The third operational mapping project with which I am familiar was performed recently at the Army Map Service. On this project, photography from a flight height of 25,000 feet and covering 1,300 sq. mi. was used for aerial triangulation by Multiplex methods to establish supplementary horizontal control. Detailed compilation and contouring was performed with lower altitude photography. The map requirement was for a scale of 1:25,000. Field checks show that the maps conform to the horizontal requirement of the national standard of map accuracy.

In addition to these three operational projects, some experimental work has been performed in mapping from high altitude photography. The Engineer Research and Development Laboratories has performed some test mapping of this type, but I am not at liberty to describe it in detail. The Army Map Service has also performed some test mapping from the photography it has procured from a flight height of 35,000 feet. These tests have been in the compilation of topographic maps for publication at a scale of 1:250,000 and carrying a contour interval of 100 feet. The first production work of this type is just now getting under way. It is contemplated that this work will involve only the Multiplex equipment, although the Stereoplanigraph may be utilized for a small amount of aerial triangulation where vertical control is too widely spaced.

In the field of reconnaissance photography, I believe all accomplishments from high altitudes to date involve the military services. Extensive reconnaissance was done during the past war at high altitudes and the resulting photography was put to extensive military uses. The altitudes involved were similar to those used for mapping, since in many cases the missions were one and the same. However, since fighter type aircraft were used for reconnaissance photography more extensively than for mapping, it is likely that somewhat higher altitudes were used, although I am unfamiliar with the details of this field. Since the end of the war, development in this field has aimed at higher altitudes, and reconnaissance photography can be expected from altitudes as high as we find airplanes going. Your guess is as good as mine how high this is today. Even though development work is under way in this field, I doubt that the military services have actually performed much operational reconnaissance photography from high altitudes since the end of the war.

CONCLUSION

Thus far, I have attempted to point out to you that there is going to be a continuing demand for high altitude photography, and that this demand will be for higher and higher altitudes. I have also pointed out that this demand is the result of economic considerations when applied to mapping and reconnaissance requirements. I have also pointed out some of the problems in the flying and use of high altitude photography, and what I know of accomplishments in the field to date so as to allay those fears that may arise concerning the utility of such photography. Before concluding, I should like to point out what seems to be the things requiring further development in the field of high altitude photography. The first thing is the airplane, and more particularly, the airplane available to the commercial field. For the present, the commercial operators are tied to surplus and obsolete military aircraft. These can not last forever. They need an airplane that will go to still higher altitudes, that provides pressurization, that provides ample speed and range for photographic tasks, and yet that only requires a capital outlay that is within the grasp of our commercial operators. Should the solution of the airplane problem result in a single-place ship, then navigating devices will be required to enable the pilot to navigate and to perform the photographer's normal duties from the pilot's seat. In any event, pressurization will probably require the use of remote controls for the photographic equipment, in order to reduce the size of the pressurized compartment. On the photography side, the principal item requiring development is a longer focal-length camera or cameras having high-resolving power characteristics and covering wide angular fields. If such a camera can be made to serve precision photogrammetric purposes simultaneously, so much the better. If not, then it would be useful to secure duplicate and simultaneous large scale cover, along with the cover afforded by present precision cameras. And as camera resolution is improved, it may be necessary to give more attention to the resolution of the film employed.

In conclusion, I should like to give you some figures which I hope will serve to emphasize what the use of high altitude mapping photography can mean in the way of time and costs. Let us assume that we wish to compile topographic maps at a scale of 1:250,000 with a contour interval of 100 feet for those parts of the United States not now adequately covered for such a requirement. There are at present some 1,200,000 sq. mi. of this country in such a category. It should be noted first that no additional horizontal control work would be needed for such a requirement, and only a very small amount of additional vertical control work would be required. Next let us assume that we are able to secure mapping photography from a flight height of 45,000 feet, and, it should be noted, this is entirely within the realm of the possible. To secure this photography would require some twelve airplanes and crews for a period of about two years. Using this photography, a mapping organization of some 200 people built around 100 units of Multiplex mapping equipment could complete all field and office work up to the "ready-for-drafting" stage in approximately two years. The total cost of the mapping up to this same stage would be in the order of $2.75 per square mile, a third of this being the cost of the photography. Thus this hypothetical mapping requirement could be completed to the drafting stage in a total elapsed time of three or four years and at a cost of about 3½ million dollars. The resulting product would not be a reconnaissance map, unless you consider that a map is such by virtue of its scale alone. On the contrary, the resulting map would be a standard product, made to prescribed standards of accuracy and content, the high altitude photographic materials having been "engineered" with proper consideration for the other factors involved in order to produce the desired result.

THE INTERNATIONAL SOCIETY OF PHOTOGRAMMETRY*

Captain O. S. Reading, President

IT IS a pleasure to talk to you for about five minutes about the International Society because I know there are many members in the American Society who could profit greatly by a better acquaintance with the work of our colleagues abroad. I myself, in spite of considerable attention to such matters, could profit with more attention still.

I think that any of you would realize that we have a great deal to gain from a close study and exchange of information with our colleagues abroad, if you would stop to examine the buildings and the equipment of the Wild factory at Heerbrugg, Switzerland, the theodolites and levels, the A-5 and A-6 photogrammetric mapping instruments, and the wonderful photographs made with the new normal-angle lens and glass plate camera; or the work of the Institut Geographique National in France with the Poivilliers SOM equipment; or the ingenious instruments of Santoni and Nistri in Italy; or the wet mosaics and horizontal cameras and measurements of Finland; or the economic map or photomap of Sweden; or the large-scale surveys and revision techniques in Great Britain; or, closer at home, the activities of Mr. Field and Dr. Howlett in Canada and the Royal Canadian Air Force at Rock Cliff, and Dr. Trorey's talk on reconnaissance yesterday.

* A talk given at the Sixteenth Annual Meeting of the Society, Washington, D. C., January 13, 1950.