graphed each year. With such a basic program, we would never have to rely on photographs more than ten years old for any area. This basic program would be supplemented by more frequent photography of areas in which there has been an unusual degree of land-use change.

This same interest in state and local governmental use of air photographs exists in other states. As Chairman of the Committee on Mapping and Technical Services of the nation-wide Association of State Planning and Development Agencies, it was my pleasure to recommend to the Association a complete program of the mapping, air photography, and other technical services which we felt were indispensable tools in planning for the development of every state. These recommendations were unanimously adopted by the Association at their meeting in Nashville, in May of this year, and have been called to the attention of state authorities throughout the nation.

In conclusion, I wish to congratulate the members of the American Society of Photogrammetry for the great contribution they have made to this rapidly developing science of air photography. I believe that you are making one of the most important contributions to economy and effectiveness of governmental operation, and I wish you every success in the further development of photogrammetry.

AERIAL PHOTOGRAPHIC TECHNIQUES IN FORESTRY*

Stephen H. Spurr, Assistant Professor of Forestry, Harvard University

A FORESTER is, in essence, a jack-of-all-trades. He has to know a little about a great many things, and as a result is apt to know only a little about any one thing. Photogrammetry, for instance, is fast becoming an essential tool in forest management: yet working with aerial photographs is only a minor part of the job of the forest manager.

In evolving or adapting aerial photographic techniques to forestry, we must constantly keep in mind the fact that the photographs constitute only one of the several important tools with which the forester must work. We must provide methods that will do the job rapidly and well, and yet which will not require too much in the way of equipment or training. Just as the forester must every so often take his transit out of the closet and run a traverse, so must he be able to take some photographs out of the drawer and obtain from them quickly and easily the information he requires.

Since his working tools are provided by the photogrammetrist, the success of the forester in using aerial photographs depends to a large extent upon the ability of the photogrammetrist to understand and to anticipate the needs of his colleague. I should, therefore, like to discuss briefly three points: (1) What are the forester's special needs with regard to aerial photographs, equipment, and photogrammetric techniques? (2) How does the forester use the photographs in his work? and (3) To what extent can specialized photogrammetric personnel anticipate and provide the ultimate information which the forester requires?

First, as to the specialized needs of the forester. These can be pointed up by remembering that the forester is primarily interested in the trees themselves, and only secondarily in the ground beneath them. That means that the most

* Paper given before the American Society of Photogrammetry, Philadelphia, Pennsylvania, October 7, 1948.

essential qualities in aerial photographs from the standpoint of the forester are: first, pictorial images of the highest quality; and second, adequate pictorial contrast within the forest by which various forest types, values, and condition classes may be recognized.

Accuracy in terms of mapping error is not important in forestry. Forest stands are large and their boundaries indefinite at best, so that mapping errors of many feet are allowable in most cases. Accuracy in terms of photo-interpretation, however, is of paramount importance. Non-compensating errors in identifying tree species, measuring the height of trees, or estimating the density of forest stands may have serious consequences. Normal summer panchromatic photographs, for instance, may permit accurate estimation of tree heights and stand densities, and yet be of limited forestry value because they fail to distinguish between pine and hardwoods, where the former type may frequently have four times the volume and value of the latter in stands of the same size and over-all dimensions. On the other hand, normal infrared photographs may give a clear picture of the distribution of forest types, and yet be equally limited in value because the excessive contrast limits the accuracy of tree measurements. To take another example, the Multiplex simply does not provide a good enough stereoscopic image for forest photo-interpretation. Adequate interpretation requires an ability to see not only the individual trees, but, even more, an ability to study the details of each individual tree and to measure it with a high degree of accuracy.

Looking to the future, I foresee that forest mapping techniques will always be relatively crude compared to mapping techniques of the professional photogrammetrist; but that forest photo-interpretation will become more and more skilled and complex. For ordinary mapping purposes, the use of a radial line plot together with simple transfer devices of the camera lucida and projector types will ordinarily suffice. When more accurate maps are needed, the job will be turned over to the photogrammetrist. In photo-interpretation, however, we will constantly strive for greater precision. I foresee increasing use of large-scale continuous-strip photography and low-altitude obliques taken when the deciduous trees are leafless, from helicopters and other slow-flying aircraft. Positive transparencies may well find increasing use in photo-interpretation, as will greatly improved magnifying stereoscopes with parallel action mechanisms, and a host of photo-interpretation aids. Even at the present time, forest photo-interpretation has advanced far. The experienced interpreter can consistently measure tree heights with an error of less than five feet, measure crown diameters with an error of less than three feet, and make an astonishingly accurate judgement as to the kind, nature, and quality of specific trees and stands of timber.

To sum up the forester's needs then, he requires photographs taken to very precise specifications and designed to provide the utmost information and detail about the trees themselves rather than the ground below. Modified infrared photography of medium contrast, taken at fairly large scales such as 1:10,000 to 1:16,000, when the trees are in full leaf, seems to be fairly well established as the best current type of forest photography in most cases. The forester needs simple photogrammetric instruments designed to turn out reasonably accurate work at a rapid pace. Such instruments are available, but a great deal is to be desired along the lines of improved engineering and manufacture. Finally, he needs the facilities for highly precise photo-interpretation. Better types of stereoscopes are needed, as well as better designed and manufactured photo-interpretive aids, and, certainly, better quality photographs.

That brings us to the second point: How does the forester use photographs

in his work? Here, it is important to realize that actual work with the photographs constitutes only a part of the task of getting necessary information. The forester's interests are primarily in the exact species of trees, the size of their trunks, the quality of the trunks, and their rate of growth. None of this information is obtainable directly from normal aerial photographs. Even the forest photo-interpreter must spend at least two days in the forest for every day he works with the photographs.

You can readily see, therefore, that not only must the forester be able to map and to interpret detail from aerial photographs; but he must also be able to interpret detail from the photographs in the light of extensive field experience; he must be fully trained in field work; and he must know how to combine photographic and field work.

The needed results are obtained not from the photographs or from field work alone, but from a careful and judicious combination of the two. This is the crux of the forester's problem today. Here is where aerial techniques are proven or where they fail. The problem is an exceedingly complex one, and is largely statistical in nature, involving the relative contribution of two alien approaches, and a complex application of sampling techniques. Much research is in progress, and much remains to be done. We have good reason to believe, however,—not that photographic techniques will supplant ground techniques,—but that the proper use of aerial photographs will reduce from fifty to ninety per cent the amount of time that the forester must spend in the field, and still obtain the desired results.

This brings us to the last point: to what extent can the photogrammetrist anticipate and provide the ultimate information which the forestry profession requires? The answer is that he can lay the ground work, but that the forester will continue to have to do the bulk of the work himself. The photogrammetrist can provide better photographs, better instruments, and all necessary planimetric and topographic maps. Photo-interpretation, however, and the specialized processes of forest mapping and forest inventory must be done by the trained forester. He must do this work because the information he needs is not visible directly in the photographs, but must be evaluated from the photographs on the basis of long and detailed experience in the forest.

Forestry agencies, therefore, will always have need for a corps of highly skilled photogrammetrists, but the bulk of the photographic work will continue to be done by the rank and file of professional foresters. With this in mind, the forestry schools, almost without exception, have introduced courses in forest photogrammetry into their curricula. Probably more than a thousand forestry students are studying photogrammetry this very year. From such men as these, there should soon arise within the forestry profession, a large group of men trained and experienced in aerial photographic techniques; and we may foresee in the immediate future, a happy state of affairs in which the foresters and the photogrammetrists, each group aware of the problems and capabilities of the other, will cooperate on a high level, and to their mutual advantage.

PHOTOGRAMMETRY AND FORESTRY*

Earl J. Rogers, Northeastern Forest, Experiment Station, U. S. Forest Service

IN THE Northeast, we have been working with aerial photographs for some time. The Forest Survey has developed some techniques based principally on photographs that have already been taken. The Forest Service is a poor

* A discussion, during the Semi-Annual Meeting, of Mr. Spurr's paper.

organization financially. As a general rule, it does not have much money to spend in order to develop new types of photography, and so on, with which it should be experimenting. We more or less have had to borrow experience from other air places and try to put it to use. We are getting over that stage now, and I think that in the near future, we are going to see some changes. We are going to see some demands for new types of photography. You heard Mr. Spurr mention a few of them; and I believe there are going to be a lot more.

Let me elaborate just a minute, on what I am driving at. At the present time, we are using photographs of approximately 1 to 20,000 scale. A forester has to use those to interpret forest conditions, that is, our foresters do, because that seems to be the general practice. In some cases, we have used scales as high as 1 to 48,000—they definitely are not the best scale. We can do better if we had scales of around 1 to 8,000. As a result of that type of photo, I am sure we could reduce our ground work. There isn't any question in my mind. Where the balance is going to be, I don't know. We can't afford a complete coverage at that scale. It costs too much money. But certainly, we can use some kind of a sampling scheme, which is not now thought out, I will grant you, but I believe it exists. We will have to request photogrammetrists to help us work out a sampling scheme. Most photogrammetrists engaged in mapping are unfamiliar with terms of sampling. They map the country on a large area—one hundred per cent. In our particular field, we can't go out and measure every tree. We must use averages. And that is where photogrammetry can come into the picture, to help us design some method whereby you can help us reduce our field work through the use of aerial photography.

THE BROCK METHOD*

Robert Singleton, Aero Service Corporation, Philadelphia, Pa.

THIS talk will be as short, informal and non-technical as possible, since my purpose is to introduce the Brock Process to those who don't know anything about it rather than to try to tell anything new to most of you who do know something about it.

First, I should like to give a very short history. As I began to gather data for this talk, I felt more and more presumptuous about making it, because the start in thinking about the Brock Process was before I was born. The first piece of equipment, a film camera, was built in 1914, about the time I started to learn how to walk. That was done by Arthur Brock, Jr. The development of the equipment continued from 1914 through the First World War and a few years afterward. It reached its first culmination in 1921 when the map on the program was made.

Brock and Weymouth, Inc., continued the development and in the Twenties built a second set of bigger and better equipment. You will see this tomorrow.

At the turn of the decade when everything was closed down, Brock and Weymouth also closed down, and the equipment remained idle until Aero Service acquired it in 1938. Since that time, we have operated the original, larger set of equipment essentially without changes, but with maintenance, of course. We have developed a few of our own techniques, but essentially the same Brock and Weymouth Process is still being used.

Figure 1 illustrates the operations. This chart starts at the left and runs to the right.

* A paper given before American Society of Photogrammetry at the Semi-Annual Meeting in Philadelphia, Pa., October 7, 1948.