of adjustment? These are all tasks in the development of photogrammetry, both in Europe and in the United States. What is necessary for both of us is that we start using a common language, and I ask you to drop these definitions, such as United States map error. You as Americans can sell quite a lot in the world, but you create quite a lot of confusion with this kind of thing.

For contour lines, it may be that in this situation, in your aerial triangulation, you can do nothing with this kind of indication of precision. We now are all using the one single expression that gives the complete indication of the Gauss square errors.

Mr. Altenhofen has said that if you know the mean square error, then you multiply it by five and you have the possible contour line. That is easy enough. Use this expression. And we will understand each other in this simple matter. It is difficult enough to understand each other in the more complicated matters where the spirit of a people enter, so let us not make it more difficult than it is by making confusion where this is not necessary. Let us use those words which are clean from a mathematical point of view. That is what I ask of you.

Moderator Sharp: Professor Schermerhorn, that was a very interesting discussion. Do any members of the panel have any brief statements to make with regard to what has taken place at the table here?

GENERAL DISCUSSION

Mr. Eliel: In all of this discussion, very little consideration has been given to the exact relationship and total cost of the results gained by the plotting machine, with other costs which go into making up the total for a job. Actually, there are some jobs, with which I am familiar, where the stereoscopic plotting costs run only 5 per cent of the total cost of producing the map. Most of them run between 5 and 10 per cent. Therefore, if we get a stereoscopic plotting machine which is 25-per cent faster than another, it actually means a difference of perhaps 1 per cent in the total cost of the job. The effect of the amount of field control, which runs with the kind of quality machine you use, is a very important factor.

Mr. Altenhofen stated that my Kelsh truck actually had more than 1 gear. I would like to call his attention to the fact that, while some of the Kelsh planigraphs have two gears, it works in the wrong direction. My one-gear truck runs 3 miles an hour and his runs $1\frac{1}{2}$ miles an hour, because actually he is reducing the scale of the drawing.

Some mention has been made of the effect of very high altitude flying on the ability to draw complete planimetry. A balance has to be struck in this matter. We have had a good deal of experience with pictures at 1 to 50,000 and 1 to 60,000. Let us suppose you can only get 98 per cent of the planimetry correctly drawn, but the cost of drawing such a map is only 50 per cent. Someone has to decide whether it is worth while to draw that map losing a couple of per cent of planimetry, in favor of the much lower cost. Someone also has to make a decision as to whether it is not cheaper to apply higher planimetry and make up the matter of increased cost in field completion.

Mr. Bertil Hallert: My paper "Contribution to the Theory of Errors for Double Point Intersection in Space" has been mentioned by some of the participants in this discussion and has perhaps caused some difficulties. Let me, therefore, briefly describe its principles and the reason why it was written.

In geodesy, as in photogrammetry, no decisive measurement may be regarded as finished before the result can be checked. This generally means that supernumerary observations are necessary. We use these primarily to make sure that no large errors are present. But since no measurement or operation can be made without errors, systematic or accidental, we usually find that there are smaller or larger discrepancies discovered by the supernumerary observations for instance in control points. A theoretically and often practically important problem is to treat these discrepancies in a correct man-

ner. The errors in photogrammetry are generally distributed rather arbitrarily by the operator, but there must be a theoretically correct manner of treating them to obtain the most reliable practical result. Furthermore, we often want to study the propagation of errors from one operation to another, especially for making specifications or error limits, that must be correctly founded.

We know only one method for the correct treatment of errors and that is the least square method, which is used in the adjustment computation. In geodesy this method is of the greatest practical importance, and it was a very great forward step when this method was invented by the great Gauss. It gave the necessary clearness which the earlier complicated and different methods of adjustment lacked. Another very important quality of this method is that the propagation of errors may be studied in a well defined manner.

However, the amount of work for a correct adjustment of many measurements is sometimes very great, especially when the functions to which the measurements belong are complicated. This is often the case in photogrammetry and is the reason why theoretically correct adjustments are seldom obtained. For adjustment of the relative orientation under general conditions, there would probably be necessary several hours of work for a single model. This is obviously not economical. The whole photogrammetric procedure can also be adjusted theoretically correct and primarily with the aid of the discrepancies in supernumerary control points in planimetry and elevation. This would be a still larger job.

It is, however, possible to simplify the adjustment procedure to a great extent if some special presuppositions are made. How to do this is the problem discussed in my two publications, dealing with the theory of errors in aerial photogrammetry. This work started about 1938 but due to several circumstances the first publication appeared in 1944. It was written in German with the title "Ueber die Herstellung photogrammetrischer Pläne" and was only a part of the work. The second publication was printed in 1950 and is a sequel to the first one. I have mentioned the title.

In these publications the photogrammetric procedure is divided in several parts, and each of them is treated separately. The necessary normal equations are solved generally which is possible under some simplified conditions. The remaining computations can be made with the slide rule. Furthermore, some questions concerning the propagation of errors in functions can be studied easily, and the quality of the photogrammetric work can be expressed in a well defined manner, founded on the principles of the method of least squares. This manner of expressing accuracy seems to be desirable since it is founded upon the only known theoretically correct method. It gives us the possibility of talking the same language all over the world in this connection. Under the condition that different instruments are sufficiently mechanically adjusted, a correct comparison between many of their qualities may be made with the aid of the same methods. For the mechanical adjustment of the instruments, some special measurements e.g. with the aid of grids, are necessary. These measurements must also be adjusted in order to find out if the adjustment of the instrument itself is brought up to the highest possible standard, or at least to the standard required and recommended by the manufacturer.

It is possible and perhaps probable that the arbitrary adjustment made by the operators in the photogrammetric procedure is rather close to the requirements of the method of least squares. This is generally simple to check with the aid of the developed formulas.

It is important to remember that the errors in supernumerary points are mostly functions of several systematic and accidental causes. Often functions of accidental errors look like systematic errors, and it is difficult to discover the difference. The method of least squares is often the finest tool we have for making this discovery. I suppose that Mr. John V. Sharp did not separate between these two kinds of errors in his paper.

However, there surely are many different sources and functions of errors. We do not know all of them yet. Of those we know we have to use only a few in the adjustment computation in order to make the work economical. This limitation must always be remembered. We have to find out and correct some of the systematic errors as early as possible, for instance, the distortion in the lenses.

In my paper there are some special presuppositions that must be remembered. The

points used during the relative orientation must be in symmetrical positions within certain limits, and the ground must be rather flat.

We need still more research concerning the theory of errors in photogrammetry in order to explain the different phenomena and to make the methods better and more economical.

Another important practical problem in photogrammetry is the question about specifications for different parts of the work. The operator must have some information concerning the residual errors normally allowed in the relative and absolute orientation. For the determination of such specifications, it seems necessary to use the method of least squares since it tells us how far the adjustment may be brought and the size of the errors after the adjustment. Such investigations must be thorough, and among other things will involve the determination of the mean errors of a standard observation in a great number of results from practical work. Such investigations should be organized as soon as possible.

Captain Reading: I have been glowing with enthusiasm, I wanted to get up every once in a while and say, "Hear, hear," as the British do, or something of that sort, as I listened to this panel this afternoon.

I heartily agree with Professor Schermerhorn that we have had the whole development of photogrammetry in the last twenty years thrown onto the table. I hope it will be extremely stimulating to all of us, when we read the proceedings in PHOTOGRAMMETRIC ENGINEERING. I hope every word will be in it.

I have a couple of thoughts I should like to present.

There is still time to think over these matters, and to consider any question that bothers us, in the work of the Technical Commissions of the International Society. Mr. Altenhofen as the representative of the American Society of Photogrammetry, is the American representative on Commission 3, which has to do with aerial triangulation and geometric computation. Mr. Pennington is the American representative on Technical Commission 2 which is considering plotting instruments and techniques. Mr. Deeg is the American representative on Technical Commission 1 on photography and aerial navigation.

It seems to me that our greatest progress comes when we get a new method of testing or a new method of communicating what we find in varying practical experiences. We run up against these things in practical experience, and we do not know what to do about them. When we get a new method of testing or a new instrument technique or a new mathematical formula, then we make progress. We clear up questions and put our attention on other difficulties, as Professor Schermerhorn has outlined.

As you study the proceedings of this afternoon, you will either have questions that do not seem to be answered or you may have a happy thought about some way of testing instruments that you would like to see tried. If you do, please write down these questions and suggestions and see that they are considered at the International Congress which it is planned will be held in September 1952.

There is another matter. Part of my reaction this afternoon has been the belief that the Europeans are right. Photogrammetry does justify the use of the theory of errors. I know it has been the general sentiment in the United States that if you had a theodolite that could point to one second of arc, you were justified in using the theory of errors; but if you had less precise theodolites, then you would go ahead and get the best precision you could in your triangulation. The kind of images that you have in the aerial photograph together with the necessity of the tremendous number of observations, sort of balance each other to make a satisfactory orientation. That would be sort of impractical if you played with the theory of errors. But we are now getting cameras and lenses and instruments that justify the use of the theory of errors and we are now comparing results in tests which justify our talking the same language and making sure that we have the same precision in our communications that we have in our measurements.

I hope it will be possible for Mr. Altenhofen to give the quantity of measurements, the amount of work done with each instrument in establishing his estimates. The time has been so short that I know it could not have been done, but I think that hereafter both the statement of the number of observations and the mean square error ought to

appear in all our communications about measurements. It certainly is fine to have it brought out so ably this afternoon.

Moderator Sharp: Apparently, there are no other questions. Before I turn the meeting over to our President, I want to thank every member of the panel for a very interesting afternoon for all. I also thank the Members for their kind attention during the afternoon. It has been quite a long session, but we only get together once a year and must take advantage of the time we are together.

Professor Schermerhorn: I believe this is my last opportunity to express my thanks to the American Society of Photogrammetry. I am a Member although from a little farther away. We are grateful for the opportunity we had here to express our European views in many questions. I hope that you have felt that we are willing and anxious to cooperate as closely as possible with our American friends who have such enormous possibilities for the development of aerial survey.

As I told you the first day, I hope to work in the international field. As dean of the International Training Center, I hope to get the opportunity to look after the differences and the common points of view as I experienced them this afternoon.

I thank you for the kind reception we from Europe had here in these few days.

President Abrams: I should like to comment, that this afternoon you have heard six of the most scholarly addresses that have ever been presented to the Society. There was probably more thought and consideration given to these talks than ever before, giving all due credit to all the papers that appeared on the program previously.

This meeting stands adjourned.