General Discussion

MODERATOR EDWIN A. ROTH. In connection with Mr. van Praag's discussion I I should like to mention that we have a small computer which is actually computing a problem by the Herget method. The Royal McBee Corporation builds an LGP 30, which is the size of a desk. It has an input-output device which is a Flexowriter, and at the exhibit at this Convention this instrument is computing data from photographs by the Herget method. It takes almost an hour and a quarter, per photograph. Quite a few equations are being solved; in fact, ten equations with six unknowns, in floating decimal. They are being Least-Squares adjusted. There are four to six iterations, and this is what takes the time. With more time spent on this type of equipment you could optimally program it and it would take, say, 45 minutes per photograph. Counting break periods and perhaps breakdowns, in a day's work we could do with this type of computer a little better than eight or ten models a day. This, I believe, is a pretty good standard, but I will leave to you the formulation of a judgement of what a small computer can do by watching this machine compute a problem The Royal McBee Booth, Compumatix, Inc., in St. Louis programmed this problem.

From the previous discussion, it is obvious that a great deal of effort was directed toward triangulating with analytical methods. The early beginnings showed that the voluminous computations which were required prohibited the use of hand methods in chart production applications.

With the advent of electronic computers and the possibility of their price being within the means of the compiling agencies, and with improved stereocomparators being more readily available, it is highly possible that analytical aerial triangulation will become an established procedure in the not-too-distant future.

The Aeronautical Chart and Information Center for the past year has been engaged in acquiring a know-how in orienting aerial photographs by several of the known analytical methods. We have become quite familiar with the Herget, Church and British Ordnance Survey Methods. The Center has not procured equipment to facilitate analytical bridging, as yet. However, one flight of 27 photographs taken with a 6 inch camera at a flying height of about 44,000 feet was triangulated by the Herget method on an IBM 650 which had been programmed for that method. Photo coordinates were measured on the Wild A7 Autograph. The results of this study were encouraging but not enough information was available to determine wherein the triangulation failed to produce desired results. Our next approach will be to extend triangulation over a larger area where enough known control points exist so that the causes of the errors that occur in analytical triangulation can be determined.

From this background ACIC hopes to develop and utilize in production the method most suitable for each task at hand, and adapt it with some modifications to the electronic computing equipment then available.

The difficulty at present is localized in the area of precise measurements. The ideal is to have a precise measuring device that could automatically measure, code the measurements, and deliver them to the electronic computer at the speed at which the instrument computes. While this is still a dream, it is one of the requirements of automated triangulation.

Perhaps several analogue computers with digital converters could be used on stereo-comparators for an initial study of the problem.

Mr. Schut discussed the required storage. Mr. van Praag, would you tell us what storage you have on the Bendix G15D?

MR. VAN PRAAG. Yes. I realize one thing I certainly neglected to mention. The computer on exhibit at this Convention has an accessory that we call a digital differential analyzer. This is capable of doing differential equations with as many as 108 integrators, and/or 108 constant multipliers. It is just a plug-in accessory. You can iterate each of these integrators at a rate of 34 per second, which on the differential portion is considerably faster than Mr. Roth mentioned earlier; and secondly, there is another means of getting storage. Our basic machine has drum storage of around 2,160 words—but there are magnetic tape accessories which are quite rapid when compared to any other means of input-output, where you can have storage at the command of the computer. You can have a couple of these units which would give you an additional 600,000 words of storage. This would certainly remedy your storage problem.

I might add that I differ very much with the statement on the internal storage required in a computer. Essentially I think any computer that has a thousand words internally in magnetic storage available, so that it can be used for your storage overflow, is quite capable of handling virtually any problem I have ever seen, and this includes such problems as we once tangled with in an oil refinery. That was a differential equation with 1,100 integrators; when you try and ripple that back and forth, you have a few problems. The big Univac only has 1,000 words. The IBM 705, you will notice, in core storage you only have 1,000 words; you pay a great deal more for additional. It's nice to have beyond 1,000 but you are really buying it for say the two or three per cent of your problems that really require it. There are other alternate means that are cheaper and really, in the long run, probably just as flexible.

THE MODERATOR. There are two additional computers at the exhibit that have this requirement for 4,000 words. One is the LGP 30 which I mentioned before, made by Royal McBee; and the other is the Autonetics Recomp II, which has also 4,096 words of storage on a disc. These are quite small and compact machines as compared to what I like to call heavy equipment, IBM 704 and 705. You will enjoy seeing these computers at work.

DON LEWIS (Pacific Air Industries). Do you know whether any of the Government agencies have been successful in solving the problem, through any of the different machines, of adjusting the vertical of an aerial triangulation strip as well as the horizontal? I learned a while back that the Army Map Service has been working on that problem for many months. Does anyone here know what the procedure was?

THE MODERATOR. I regret that Professor McNair could not be here. He and his computer center programmed this problem for the Univac at Army Map Service. I am pretty sure it included the vertical. Mr. Tewinkel, have you any information on government organizations programming this correction for the vertical as well as horizontal?

MR. TEWINKEL. The planning every place that I know of is complete, in that it includes the vertical as well as the horizontal. They are using the Least Squares method. Perhaps Mr. Bodnar can give you more information about the Army Map Service. Or let Dr. Schmid explain what he has been working at his office. He has gone farther than I have.

DR. SCHMID. All people, if they follow the British Ordnance Survey method, use three dimensional triangulation schemes. In other words, we all consider the problem equally weighted with x, y, and z coordinates. There is no dispute that it is a correction system; it is not a first-order position; it is just a later horizontal information—but all is in a combined spatial triangulation scheme. We program it all together.

I can say in a limited way that in Aberdeen we are coding, at the moment, such problems for the IBM 703, 704, ENDAC and ALWAC. We are coding it not for the purpose of aerial triangulation, but for mathematical measurements. However, it is an identical problem; because the code isn't authoritative we have to come up with what was photographed.

THE MODERATOR. Does the Army Map Service have this program complete for their Univac?

MR. BODNAR. I know that they have been able to program the horizontal. But I understand they ran into some problems with the vertical and had to abandon it.

THE MODERATOR. There are problems throughout the whole system that have not yet been resolved, as has been pointed out. Additional information is generally required. In my opinion it is doubtful that the cantilever extension can be made with the required accuracy, and we do need the additional control on the ground.

DR. SCHMID. I agree that we need some kind of control; whether it would be ground-control or some other auxiliary. One of the things that will be very influential in the cantilever extension is that you have a definite limit of deflection and you will have closer limits of error from one exposure station to the next; these two things used in conjunction will exert a great deal of influence on the solution.

Of course, it is quite clear that any ground-control or any other fairly accurate, absolute control that you can obtain, will assist in this problem tremendously. If you have ground-control down near the end, this is wonderful, but many times you will not have it. What you must do is to actually use everything that you have at your disposal in getting the flight started in the right direction with the right scale, etc., so that you don't deviate according to a systematic error that you have set into it.

THE MODERATOR. I am afraid that the problem is in one complete mass, which may create the impression that the solutions are practically impossible. They aren't. It is just that a system will have to be worked out just as the system was worked out for the C-8 Stereoplanograph and the Wild A-7 Autograph. Quite a bit of engineering went into those pieces, and there will have to be quite a lot of effort and thought put into how we can program this problem successfully, for any condition. I doubt that it will be any one system; it will probably be more than one.

MR. RALPH HALL (U. S. Geological Survey). With the Schmid system, do you have to make an estimate of the points before you send them in? Or am I confusing two different systems? Is it necessary to put in a correction for each photograph?

THE MODERATOR. Yes, We get correction equations, and these equations have corrections of the first-order. If we could get the equations of corrections for a higher order and compute them, we wouldn't require an iteration. But in this type of problem, this is not possible, because you wouldn't know how to set up the second-order equations. Dr. Schmid or Mr. Tewinkel—you have been working with these problems.

MR. TEWINKEL. We assume that it will be necessary to enter an approximate value for each of the six parameters for each photograph; that involves no obstacle. The first approximations, of course, of Phi and Omega are always zero. Kappa can possibly be zero, or it can be measured with a protractor on a stapled mosaic or a photo-index. The flying height is z_0, we know, that's no obstacle. The x and y also can be measured very crudely from a very poor photo-index with sufficient accuracy for the problem. After that, the computation makes all the other corrections.

DR. CURTIS JOHNSON (Compumatix Inc., St. Louis, Mo.). I have one question. I think I probably speak for Mr. van Praag and for Dr. Cohn at Washington University. Any of us who are working with computers find that our greatest difficulty in talking with someone who has a problem is a mutual understanding of what the problem is. Photogrammetry is something which I hadn't heard of until a few weeks ago. There are a lot of terms with which we are not familiar, and unfortunately we are not a large enough concern that we can go out and get help from a couple of consultants who understand photogrammetry. Mr. Roth has done his utmost to pound some of the mathematics through our heads. Right now is there a clear, concise, complete statement of the problem; a complete definition of the procedure and methods? If so how can we get a copy in the computing field, so that we can properly understand your problems and work with you? I gather that Mr. Schut has made a good start toward comparing the various methods and showing the derivations, the definitions, etc. Perhaps his writings will be most valuable to us. But I want to enter a plea that this is something which those in the computing field must have if we are to move forward with the greatest speed in cooperating in solving the problems.

THE MODERATOR. I ask the members of the Panel whether there is any publication that is entirely complete. Mr. Tewinkel, do you have in one form the complete method that you are using?

MR. TEWINKEL. As a basic text I am using Dr. Schmid's Bulletin 961. I am translating that in my own notebook into my own language; perhaps it will be useful some day to somebody.

THE MODERATOR. I assume this report 961 contains all the equations. The Least Squares adjustment according to Gauss' method? Isn't that right, Dr. Schmid?

DR. SCHMID. Yes. Several times the complexity and complications of this problem can be described as nothing more than "Sophomore geometry." I now have good news, in that I have made, in the very recent past, a step forward which is three steps backwards; and simple as it is today considered, still complex. So therefore it is my feeling that it is the bookkeeping for the computer which is complex. In other words we are dealing with relative points, positive points, given in height or only in x and y; and all these things which forced the poor computer to almost think in factual terms. It is storing a lot of different challenging approaches to be prepared to pick up whatever is necessary for the specific case. Mr. Tewinkel has actually said what I now have in mind and where I had numerically computed examples proving that the whole problem is nothing but a three-point problem in a straight line. Because it is possible to derive all conditioned equations from this basic symbol and condition of analytical geometry, it was actually not reasonable to go farther. As everybody so far has reached his condition equations, and Mr. Schut has spoken of five different approaches, all have arrived at the same straight-forward condition which expresses image points, nodal points and given points, xyz, all lying on a straight line. Because we do not know the given information it was substituted for, it was taken out in our formulation. Now in my new approach I use these points as if they were known, even from a relative point. In other words, I carry the x, y, z's additionally as unknowns so that it would use, in effect, the whole approach to the fact that we have only to deal with one kind of points and the whole difference. If it is a relative point or an absolute point, the computer is told in the first case that I do know my z coordinate, consequently I have only x and y as unknowns to worry about; or second, you know all three and it is automatically an absolute point; or you know nothing, then automatically out of the solution will be computed the x, y, z coordinates of said point. At first glance, it appears ridiculous to try to orient a vector against something which you do not know, but if you do start with two of these vectors and allow or make sure that they are oriented to the same point, that means nothing but to intersect. In other words what we eliminated algebraically beforehand, we are now eliminating through the process of computation. And that streamlines the approach and makes it very simple for the bookkeeping.

THE MODERATOR. Could you tell us how to get a copy of these Reports 961 and the new one?

DR. SCHMID. I do not know the number of the new report. If somebody is interested in our reports, he needs only to write to Aberdeen Ballistic Research Laboratories, Aberdeen Proving Ground, and state that he wants reports on photogrammetric methods they are developing. They are freely supplied to anybody.

THE MODERATOR. A lot of these things have been published. Mr. Tewinkel said that any Sophomore could solve these problems, or something to that effect. What I say is that I believe any Sophomore would realize that he will have to go into his Junior year in order to get some of the mathematics he needs. This is a point of disagreement. Mr. Tewinkel, would you discuss this a little further?

MR. TEWINKEL. I intended to say that it could be demonstrated to the satisfaction of a Sophomore. I don't think that a Sophomore could create it. That is, the Sophomore would have all the background at the middle of his Sophomore year to understand the complete matter. You don't have to use vectors or use matrices for a demonstration. Those are nice to use; they save an awful lot of type in typesetting for a publication. But they are not necessary.

THE MODERATOR. Dr. Pepper, would you tell us where these reports of the Herget method, or anything that you have done at Ohio State University, are available?

DR. PEPPER, I should have said somewhere in my talk that the Herget method was developed under Air Force sponsorship; without that statement I would be violating a contractual condition. The specific reports are Ohio State University, Mapping and Charting Research Laboratory, Technical Reports No. 179 and 201. These reports develop the theory. The first one is in connection with Shoran positioning, and its application of the equations to the use of the Shoran positions in the triangulation. The second one is of a more general variety, giving the control extension. There will be one coming out very shortly that has to do with the propagation of errors essentially in an actual strip triangulation. We will have an example included. As far as the unification I have talked about: I took the title of this Panel literally, and I looked to the future. These things are not complete, except in rudimentary form. I feel certain that the details can be carried out; but they are not yet complete in any reports anywhere.

THE MODERATOR. Mr. Bodnar, can you tell us about any ERDL reports that are available?

MR. BODNAR. At ERDL we are using a modification of the Herget method. The method of course was developed at Dr. Pepper's organization. The modification was developed by Cornell University and some copies of the reports are available from Professor McNair at Cornell University. Cornell is presently working on another system that will also provide a simultaneous solution similar to the Schmid method; no reports are available as yet.

THE MODERATOR. Some of the reports that Dr. Pepper has just mentioned are in photostated form and located at the Armed Services Technical Information Agency at Dayton, Ohio. We can give the full addresses later. Mr. Schut, can you tell us where some of your work will be published?

MR. SCHUT. To prepare ourselves for a conference in Ottawa last August on Aerial Triangulation we studied different methods that we could find in the literature. We found nine methods. I made a study of all. A detailed analysis complete with formulas will be published in one of the next issues of *Photogrammetria*, the Journal of the International Society of Photogrammetry. All these different methods and formulas and the methods used at Ottawa are given in the kind of notation that you saw on the screen here.

THE MODERATOR. If you are a Member of the American Society of Photogrammetry you will find that a few of these methods have been published, and included are footnotes that refer to published reports. For instance, Professor McNair has written twice; once in September 1956, he presented the partial problems with which some of us disagree; the June 1957 issue contained the second. Another one of these papers is by Dr. Shu formerly a mathematician at Cornell,* To some it may be surprising that the MANUAL OF PHOTOGRAMMETRY contains very little on analytical aerial triangulation; but that's quite understandable. You have gathered that this is a future method and the tooling-up process is a little tedious. If you want a production line method, we must resolve all of our difficulties and get one method, or a series of methods, that are used under certain conditions, in which you can perform any triangulation that you want.

MR. ESTES (Aero Service Corporation). Dr. Pepper, you talked about utilizing the other information such as the Shoran and the APR (Airborne Profile Recorder). If APR information is to be used, it must be that from selected points. Do you have any regular manner of selecting surfaces?

DR. PEPPER. Yes. Of course, in some things like verticality you can use at every aircraft station. But you must have something that is identifiable as being essentially the same. Relatively level, the same in the two exposures. The surface of a lake or flat field might be an example. Of course you are taking a chance if it isn't a body of water, the field may have have a slight slope and throw you off. But if you have some identifiable boundary of this, then you can get approximately the same point; if the slope is gentle I presume that you won't have too much difficulty through saying "It's approximately this amount." The reliance that you put on it, the weighting factor that you use, would depend on how well you feel there is a determination of being the same elevation.

It's a calibration problem in two ways in this particular case. The general calibration, how much weight can you place on this type of information in general; and then again, how much weight can you place on it specifically. If you are identifying a peak, a little lateral shift might give you quite a difference in elevation.

MR. VAN PRAAG. We have sold the Army Map Service a G15D computer and we have taken a contract from them to write quite a series of programs. These are just about coming to a conclusion. If any of

* See also PHOTOGRAMMETRIC ENGINEERING, December 1957, p. 962—EDITOR.

you are interested in receiving the descriptions of these programs, we will be happy to mail them to you. These will be written up in our normal form, which is to define the problem pretty exactly, all the terminology, so that virtually anyone should be able to understand it and the description of the method, including a flow chart, etc. I don't know exactly all of the programs that are under way, but we have had two people working on this for about eight months. I sincerely hope that they have turned out something productive. But I can't resist saying to Dr. Johnson that if he wants information, "come on in and bring your money, Kid."

THE MODERATOR. That's the big problem, money. At a tour that we will have tomorrow to Washington University there will be seen a sample problem being computed on the IBM 650. This is one of the machines that has 2,000 words storage. There can be seen what getting normal equations and inverting a matrix requires; a bank of lights flashing for about ten minutes, and out comes an answer. We didn't perform the iteration on it, because that would have run a bit too long.

DR. PEPPER. On point identification strange things can happen. We tried the cantilever extension in which we used control only in the first plate; having used this control there, we said: "These coordinates are the given ground coordinates; let us use them now in all plates in which they appear." So for this cantilever extension, we made a computation. Strangely, at about the third plate, there was an abrupt deviation in the direction of the strip. We ran it out to the end, it ran smoothly out; we thought, "Well, this is just because we had some bad data in the beginning." So we said, "Since the end of the strip is nice and smooth, let's start from the other end." We had control on the whole strip, but we weren't going to use it in the triangulation. So we tied the other end down and started the same way; lo and behold, we got a similar type of "bend" at the end of the second plate. This led us to wonder what was wrong. We analyzed it, and decided we must be using the ground-control coordination with too great a strength after we had tied down that first plate. Now, when we had pretty good coordinates for them, how could you say we were using them with too much strength? Well, it turned out in our analysis that the plate-to-plate identification was superior to the ground-to-plate identification; therefore we were wrong in using as passpoints the coordinates of the ground control because in the photography—rather poor photography, but all we could get—we had misidentified enough to throw this in a warp by accentuating the misidentification of the ground-to-picture coordinates. You must be able to identify what you are looking at both in the photo and in the plate, and have the same point, or you won't get what you expect.

We did, by our reasoning, solve this problem and get a fairly smooth triangulation out of it by computing some fictitious coordinates. We had the photography over ground which was reasonably level in the first control photograph. We assumed the elevation of the ground-control point, and computed the horizontal positions of the object we identified in the plate as having computed coordinates, plus the elevation of the ground-control point; and using these points, we got a nice, smooth fit of the subsequent photographs into the one at the beginning. It gave us a reasonably good fit as far as we felt the photography justified. We *did* get around the bend; but it shows that you must be careful what influence you give to a point. This was a case where we forced exact fit to ground control when we should have merely given an influence, using the elevations.

MR. DON LEWIS (Pacific Air Industries). The idea that I have is one of concept, actually, in fundamental approach to the problem. As Mr. Tewinkel said, he thought they would have to select twelve or—how many points per photograph? The more points you use, the better the strength of your solution. Compare that, then, to the machine solution where the human eye (or the operator), in observing a model, has this infinite number of viewed points which fuse. By observation and just this visual fusion, you have an indefinite number of points to give a check in a bridged surface, a viewed surface. When you base your mathematics on a few points, you are hinging on the possibility of making mistakes on one, as Dr. Pepper has pointed out. He warped it for one point. In your visual model, you have thousands of points which you can see; you can get a flow; just your viewing of your models establishing a continuous ground surface may be a factor that, in eliminating, may con-contribute to the weakness of your solution.

THE MODERATOR. Dr. Pepper has a few words to say regarding comparing instruments with computing methods, I believe.

DR. PEPPER. Perhaps I am reporting this too soon since it isn't yet in report form. Whether it be in the Stereocomparator or an optical instrument such as the Wild A-7, the Zeiss instruments, The Santoni, or any other, stereoscopic viewing does improve the identification of the point of which you are trying to get the coordinates. On the other hand, assume you have made either a stereoscopic coordinate measurement or a stereoscopic instrument triangulation, the former being followed by a computing machine analysis. We ran a strip on the A-7 of the same photography that we had run on this other. The man who ran it was a very experienced photogrammetrist, and he was sure the instrumental triangulation was going to be considerably better than the other. It turned out, however, that statistically, from the photography we had, there was no significant difference between the best triangulation with numerical data and the best triangulation on the other. We also made some studies in connection with how many points one should use per photograph —how many points per model, perhaps I should say, because you are more familiar with this way of terming it. We have reason to believe that six points per model is probably about as many as you need to get into the law of diminishing returns; that is, nine points per plate or six points per model, provided these are well-identified and well-measured points. We have run this one strip with four points per model, six points per model, fifteen points per model—I'm not sure whether we have run any intermediate ones. We measured twenty-five points per plate to begin with, and then we made selections from these.

There is one thing, however, where we did have to be careful, and that is misidentifications which were obviously "bulls." You identify something in this plate, and completely misidentify it over here—and it will stand out like a sore thumb if you use more than four points per model. If you use only four points per model this won't show up; it will just give your model a twist. So you really dare not use the minimum number of four points in order to avoid these "bulls." You must use more than four, and then if one is a "bull" it will stand out; so far as you know it has to be thrown away; the rest of them are used, and the coordinates are tied together. We had to do this in a couple of places on the strip—throw out a very bad observation—and then we came out with what was statistically predictable within the measurement errors and the identification limits on the photography we had.

The photography was very poor. We predicted a very large closing error from the statistics of the reliability of the observations. I think we were about 450 feet out (this is in the ground scale, of course); I think the photography was flown at 20,000 feet, using a 6″ focal length lens; we went through a series of 13 photographs. Strangely enough, the instrumental came out 450 feet off, roughly; within plus or minus what we would expect. This is not very good because the photography was made five years after the control was identified; the descriptions were that much out of date; there had been a lot of construction in the area, and some of the control was completely unidentifiable. But it gave us something which was self-consistent. We knew the photography was bad; we came out with the expected results, approximately.

MR. LEWIS. How many models in that strip, Dr. Pepper and what camera?

DR. PEPPER. Twelve models in the strip. The report will give the statistics. I am not sure of the camera, it was some photography we got from U.S.G.S.

THE MODERATOR. It probably was the T-11 camera. I should like to make one remark: with any of these methods, you cannot improve on your observations. This is true with practically every type science, except perhaps by statistical methods. I believe Mr. Blachut has a question.

MR. BLACHUT. It is not a question, just a remark, because I feel much disturbed by a remark just made. In instrumental work you are using, for relative orientation, five points. If you are using six and you have some remaining parallax, it is more or less up to the operator to decide what to do with this remaining parallax. That is exactly the point where the analytical method is far superior, because when using five points in relative orientation (of course assuming this same accuracy in the stereocomparators and ordinary plotting equipment), the results should be approximately the same. However, if using an analytical method, we have this facility of using more points and then the remaining parallaxes (always existing, due to the inaccuracy of photographic images) can be thus cast out; it must be decided in a mathematical way. Therefore, any speaking about an infinite number of points which are used in instrumental work, is just not true.

THE MODERATOR. Thank you, Mr. Blachut. We mentioned earlier, in automation, we would like to get the arbitrary decision element out of this; and I think this brings out the point very nicely, about eliminating the worker.

If there are no other pertinent questions, I will take this opportunity to thank the members of this Panel, who have so graciously come, and stayed this length of time, to present what we believe are the problems and how they can be resolved.

Biographical Sketches of Participants

EDWIN A. ROTH was born and educated in St. Louis, Mo. and is a graduate of Washington Univ. with a B.S. degree in Mathematics and Astronomy. He served with the Army Air Force from 1940 to 1945 and participated in the European campaign. In 1948 he entered on duty with the Aeronautical Chart and Information Center where he is presently employed in the Photogrammetric Equipment and Techniques Office as a consultant and specialist in the application of mathematics to photogrammetry.

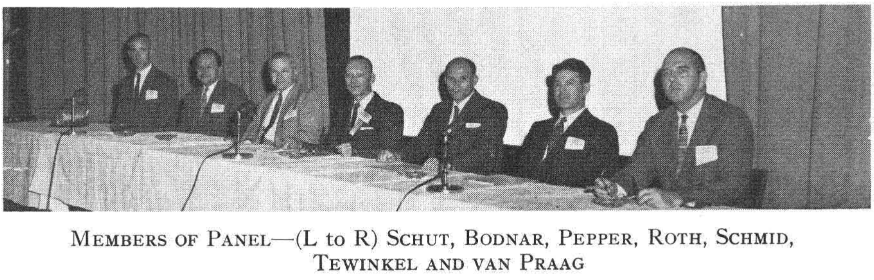
He was the second President of the St. Louis Section of the American Society of Photogrammetry and is the author of two papers which have been published in PHOTOGRAMMETRIC ENGINEERING.

DR. PAUL M. PEPPER obtained his elementary and secondary schooling in Fort Wayne, Ind. He attended Indiana Univ. and obtained an A.B. degree in 1931 and a M.A. degree in 1932, both in Mathematics. From 1932 to 1937, he was the grantee of various graduate fellowships at the Univ. of Cincinnati where he obtained his Ph.D. degree in Mathematics in 1937. Honors: A.B. cum laude, Phi Beta Kappa, Sigma Xi, Alpha Pi Mu.

He was Instructor in the Dept. of Mathematics at the Univ. of Cincinnati from 1937 to 1938. Between 1938 and 1949 he rose from Instructor through Assoc. Professor of Mathematics at the Univ. of Notre Dame. In the summer of 1947 he was Research Fellow in Aeronautical Engineering at Harvard Univ. In 1949 he joined the staff of the Dept. of Industrial Engineering of The Ohio State Univ. as Assoc. Professor. He was Research Coordinator and, later, Asst. to the Director of The Ohio State Univ. Research Foundation, 1951 to 1953, 1957–, he was Director of the Mapping and Charting Research Lab. and Assoc. Professor of Mathematics from 1953 to 1957.

He is author of published papers in pure mathematics and in its applications to metallurgy and industrial engineering. He holds a patent on a calculating device. He is a member of several technical and scientific societies.

G. C. TEWINKEL has been employed in the U. S. Coast and Geodetic Survey in Washington, D. C. since 1941. He is chief of a small unit engaged in photogrammetric research, development and training. He was formerly employed by the Soil Conservation Service and by the U. S. Forest Service in Spokane, Wash. He is a



MEMBERS OF PANEL—(L to R) SCHUT, BODNAR, PEPPER, ROTH, SCHMID, TEWINKEL AND VAN PRAAG