

# Review of the Third Edition of THE MANUAL OF PHOTOGRAMMETRY

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YOU MAY ASK why I have been chosen for the honor of reviewing the MANUAL. The answer is simple: I am the only person left from among the leisured classes who is not an author.

It has been said about the *Principia Mathematica* by Bertrand Russell and A. N. Whitehead that the work has never been read from cover to cover by any one person: not even by either of the two authors. I feel sure that it would be a safe guess that the 3rd Edition of the American MANUAL OF PHOTOGRAMMETRY will be superseded by a fourth before it has been read by all of the 100 individual authors and all of the 50 Presidents and Heads of Organisations that have contributed to this monumental work. We may assume that Morris Thompson has read it all; and we also may assume that your reviewer has read it all: "a thousand pages in my sight are but an evening gone." Reviewers, by convention, are supposed to have read what they review, though authors, as a class, are often ill-bred enough to suggest that the reviewer does little more than look at the Foreword and table of contents. I am not denying that much can be done with this data: for, as every scientist knows, facts are inhibiting and one's best work is done without their help. I will leave it to the 100 authors to decide what I have read and what I have not.

It is, I think, very unusual to be asked to review a book in public, and it is a somewhat unnerving experience. There is no hiding behind complete anonymity or even behind the partial anonymity of initials—with the middle one left out for good measure. And the matter is made no better by the knowledge that the audience has a very high author content and consists besides almost entirely of publishers, who are not going to be very pleased if what I have to say will not induce the public, or what remains of it, to buy. Lest therefore anything I may subsequently tell you should cause misunderstanding, I now state quite unequivocally that the new edi-

tion of the MANUAL should be bought by every serious photogrammetrist. This constitutes the sincerest form of flattery. I am writing a book at the present time and I intend to make considerable use of the MANUAL.

On a public occasion such as this perhaps I should preface my remarks by telling you what I think a reviewer should attempt to do. He should, in the first place, let his readers know what the book contains, though this is something that becomes less and less important as publishers adopt more and more modern and aggressive selling tactics. My desk is often covered with leaflets describing the contents of and giving extracts from the latest scientific publications. What the reviewer has to say on this score is therefore likely to be redundant; and it would be more valuable if he were to concentrate on what the book does not contain: information we do not usually expect from the publisher.

Then I suggest that the reviewer should examine what the book sets out to do and in what way it falls short of this goal. Particularly in the case of a publication such as the MANUAL which has already run into several editions and will, no doubt, run into more, the reviewer's remarks, however critical, should not be resented because, if they have any substance, the editors can profit by them in a subsequent edition.

The writing of any book is difficult: but the writing of a technological book presents very special difficulties. If, as the Editor says in his preface to the third edition, one of the main reasons for its publication is to produce an up-to-date manual then it is essential that the authors should themselves be up-to-date. They must, therefore, be practitioners and such, with a few exceptions, is the case here. To quote from the Preface, the Editor says "The authorship of the Third Edition truly represents a comprehensive spectrum of practice in the field of photogrammetry." But a practitioner is not always the best person to write a text book. If he is well aware of the latest developments, or at any rate of those with which he is in day-to-day contact, he is likely to be less aware of the principles on which

\* Presented at the Annual Convention of the American Society of Photogrammetry in Washington, D. C., March 1966.

these developments are based and even less aware of what is important to a student and how best this can be presented. This last person must be a teacher, but a teacher, with the best will in the world, cannot be up-to-date even if, as some would doubt, he is otherwise competent; "those who can, do, those who can't, teach." So we really fall between the two stools and I have reluctantly come to the conclusion that books on technology must, in one respect or the other, fall short of the ideal. To give one simple example of what I mean, and I give it not because it is so important but because it is clear-cut. I see no mention in the *MANUAL* of Desargues' theorem which is 330 years old this year and on which, as every academic mathematician knows, the whole theory of perspective depends. To ignore this theorem is to make the theory of optical rectification not only difficult to understand but considerably more complicated in presentation.

In the absence of any specific statement on the aims of the 3rd edition of the *MANUAL* we can deduce from the Preface that its object is to present us with an account of the up-to-date practice in photogrammetry; and we may therefore assume that such principles as appear are intended to be more in the nature of introductions to the practice rather than as forming a systematic treatment of theory to be studied as a consistent and continuous whole. For example, Chapter II, entitled the Basic Mathematics of Photogrammetry, contains very detailed descriptions of the determination of tilt and of the elements of outer orientation by space resection methods, which must surely be regarded as practice, while at the same time it omits the very important elements of projective geometry we find at the beginning of Chapter XVI, Transformation and Rectification, that one would expect to be devoted essentially to practice.

While this is a perfectly logical point of view to take, the danger is that an important basic principle is overlooked because an author thinks it too elementary to mention in his own chapter, being under the impression that it would obviously have been stated elsewhere; and it would be asking too much of the Editor-in-Chief that he be held responsible for checking this. Here are two examples of such omissions: I have not been able to find anywhere, and especially in Chapter II, a clear, unequivocal statement that the reconstruction of space is not possible from a single photograph; and it is surely the use of photographs to reconstruct space that differentiates photogrammetry, as we understand the word

(or at any rate as I understand it) from the simple measurement of pictures that is its literal meaning. Although the first paragraph in the *MANUAL* appears to take the wider meaning, yet the context makes it quite clear that we are in agreement on this point. Secondly I see no clear statement of the unknowns that the photogrammetric problem presents for determination; and how these unknowns are divided into the groups of parameters of internal, relative and absolute orientation. If I have missed such an exposition, and I may well have done so, it is certainly not to be found where it should be found: in Chapter II.

I find myself forgetting that this is an American *MANUAL*: for the inclusion of authors from overseas has given it a somewhat international flavour. Nevertheless it is an American *MANUAL* and hence the practices described tend to be American practices. For this reason I do not criticise, but must nevertheless confess my surprise, that so much space is devoted to problems that I would have thought had long since ceased to have any practical importance, such as methods of tilt determination of the single picture, and studies of the behaviour of scale on the picture.

At the same time, the authors of Chapter II are to be congratulated for having had the courage to introduce matrix ideas and I would have preferred to see the appendix to the Chapter considerably expanded at the expense of some of the earlier material of somewhat doubtful usefulness.

It will be noted that, in the terminology of Boolean Algebra, the intersection of the two classes of authors of Chapter II and X, Analytical Photogrammetry, is equal to the class of Chapter II authors. That is to say, all of the authors of Chapter II have contributed to Chapter X\*. You will have noted that I have not been over enthusiastic about Chapter II, but I am happy to say that the distinguished team that wrote Chapter II has helped to make Chapter X one of the best in the *MANUAL*. I have the impression in fact that they were determined not to steal their own thunder. I wonder if I am right?

Although the detailed analytical descriptions are confined to methods which have been adopted in North America, and I cannot see how we can complain about this, Chapter X is, in my view, by far the best presented of all those that deal with what, for want of a better expression, I would call the theory of methods. It is logically set out and has a continuity and unity which represents a

very high degree of cooperation among the authors. A reader of this chapter should be able, if not to carry out all the work himself, at least to understand the principles underlying analytical photogrammetry and to follow out more than one particular method in detail. I would even go so far as to say that this chapter is a better introduction to the basic mathematics of all kinds of photogrammetry than is Chapter II.

An important advantage of analytical (perhaps we should really call it digital) photogrammetry, over analogue photogrammetry is the freedom it gives the photogrammetrist to correct the geometrical defects of the photograph. The attention paid to this is not one of the least important parts of Chapter X; and it gave me great satisfaction to note that the correction for earth curvature is stated as something to be applied only if it is found impossible to compute the triangulation in terms of a space coordinate system. All I would ask is, why is it ever impossible to do this? I can only suppose that the Author-Editor did not have the courage (and I cannot entirely blame him for this) to throw it out completely. It is one of the more depressing aspects of science and technology that the evil that men do lives after them. I say depressing because these subjects set themselves up as rational, objective, and progressive and therefore have no excuse for being otherwise.

Consider, as an elementary example of this, Euclid's algorithm for finding a square root. For two thousand years children have been forced to learn, without understanding, a complicated procedure difficult to remember, while, since Newton's time, there has existed a very simple process whose logic is obvious even to someone with no knowledge of algebra. Newton's process is to be found only in advanced books on computation: the school books still prefer Euclid. Consider another example more appropriate to the present occasion. Elementary text books on optics have, since Huygens' day in the early 17th century, given the lens formula

$$(1/A) + (1/B) = 1/F$$

Not only is this formula difficult to handle both arithmetically and algebraically, but it obscures the structure of the mechanism that transforms an object into an image and thereby makes it difficult to understand how the transformation can be represented by a mechanical analogue. Newton's formula

$$XX' = F^2$$

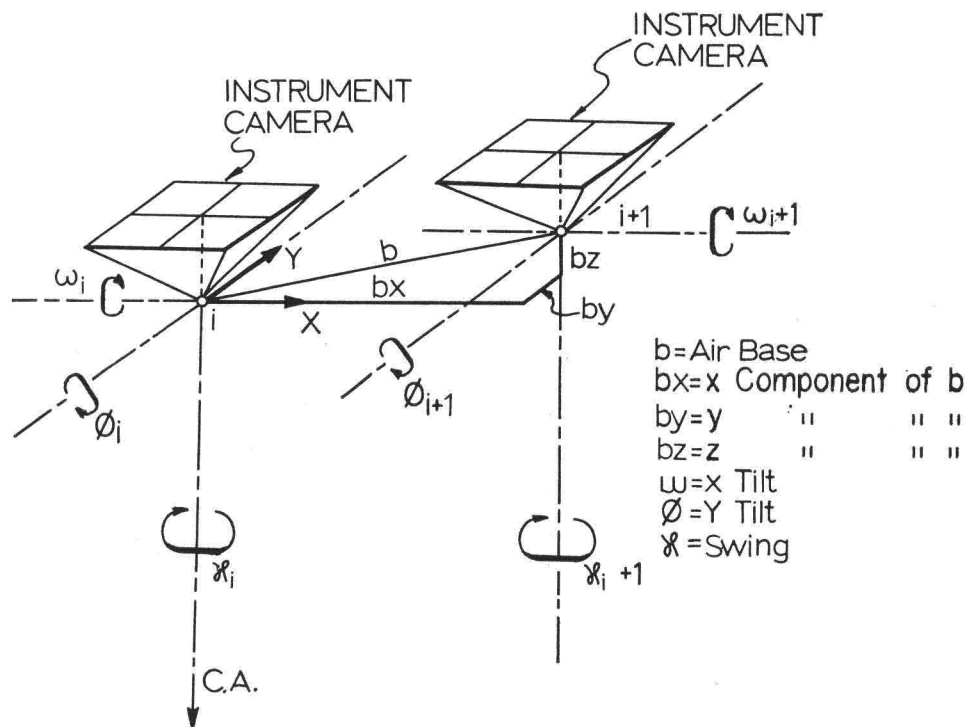
has none of these disadvantages, but it is only

to be found in books on technical optics. School-children have been deprived of it for the past three centuries and will, no doubt, be deprived of it for the next ten simply because Huygens got in first. I am very happy to say that Chapter XVI on Rectification makes considerable use of the Newton formula.

May we hope to see earth curvature correction thrown out entirely in the Analytical Photogrammetry section of the 4th Edition? And why not as well from Chapter IX where it plays a disproportionately large part?

Chapter IX is concerned with all methods of aerial triangulation with the exception of the purely analytic method which, as we have seen, is very well considered elsewhere. I find the chapter a little uneven: half is concerned with the practice of the slotted templet methods and this is excellent and will provide an authoritative and handy reference for all who wish to use the system. I regretfully note, however, that the theory of the errors of the radial line assumption is based on image point displacement which is difficult to follow and can lead to misunderstanding: in fact, the formula given for the error due to relief is incorrect. It is yet another example of what I might begin to call Thompson's Law of Inertia (any generalisation is a Law if at least two examples can be found to satisfy it). The mistake was originally made before 1930 in a British textbook and has since found its way into numerous publications including the first, second, and now third editions of the MANUAL. The chapter contains a very careful analysis of the error propagation in an aerial triangulation which could I think be improved only by using more sophisticated language to describe what the author calls quasi-systematic errors. These are simply the errors of variables which are linear functions of (statistically) independent variables and therefore, in general, correlated, sometimes very highly. For "quasi-systematic" we therefore simply mean "correlated."

The adjustment procedures for individual strips are well-described, but the most disappointing feature of the chapter is the lack of a serious attempt to set down the digital methods of block adjustment now current, more than one of which have been developed in N. America. I do not, of course, know the time scale of the production of the MANUAL and it could be that it was impossible to include the more recent methods; there is, however, no such excuse for having given such a cursory treatment to relative orientation. This criticism applies not only to Chapter IX but also to Chapter II. I know that there is a view

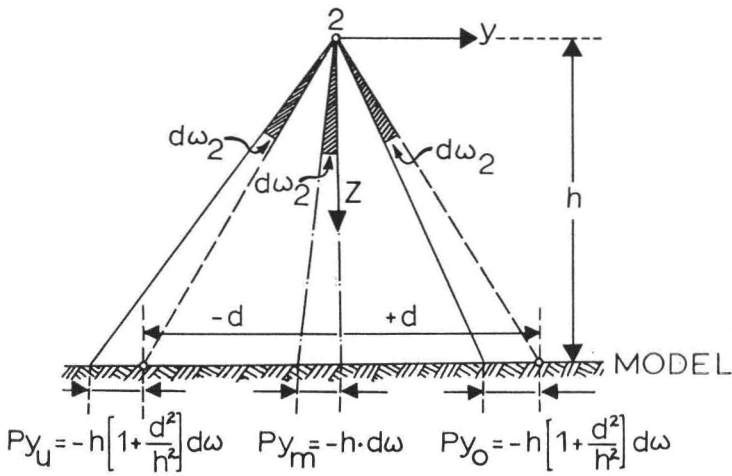
FIGURE 9-18. Elements:  $b_x$ ,  $b_y$ ,  $b_z$ ,  $\omega$ ,  $\phi$ ,  $\kappa$ .

that we can dispense with relative orientation as an explicit procedure in analytical methods: I am not convinced of this but I am not going to argue the point here. What is absolutely clear, however, is that it is an essential part of any work with an analogue plotter of whatever type. It is therefore surprising that the geometrical theory of relative orientation is not dealt with anywhere in the manual, and especially not in Chapter II where I would have expected to find it. The practice is well covered in Chapter IX which we are now discussing and in Chapter XIII which deals with the optical projection group of plotters; it is the theory that is lacking.

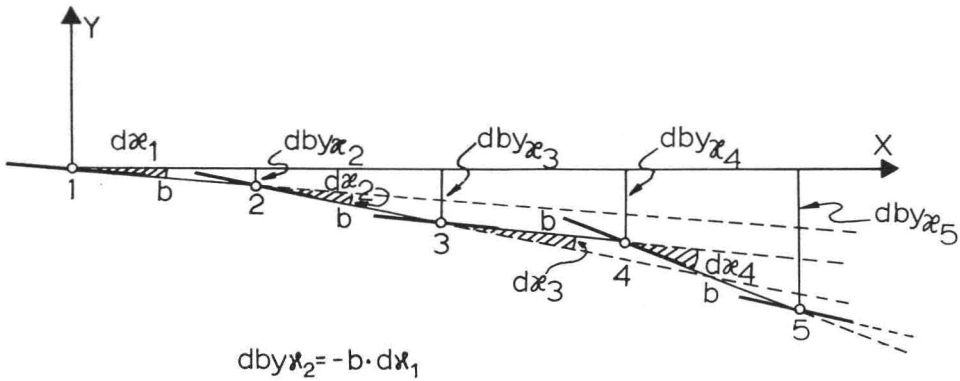
In delivering this review, I am in a position that is unlikely to recur for fairly obvious reasons. One can always complain about minor irritations, but if one does so spontaneously it gives one the reputation of raising unnecessary and trivial difficulties. If, however, one is asked to criticise, one cannot surely be blamed for doing so. I very regretfully see in Chapter IX, Mechanical Methods of Phototriangulation, the first signs of the spread of a pernicious European disease from which I had supposed North Americans to be free. On page 398 there is an entirely satisfactory diagram (Fig. 9-18) showing what is understood by base components, which, as we

all know, are simply the differences in coordinates of two adjacent air stations or vertices. In other words a base component is something associated with two vertices: it has no meaning therefore when applied to one vertex. If, however, we look forward to, say Figure 9-20, we see what are clearly the errors in the  $y$  coordinates of the vertices labelled with the symbols  $db_y$  and an appropriate suffix. In other words, the symbol that started life as indicating a base component has mysteriously become one for indicating a coordinate. This seems to have become a universal European habit, but when I do not know, because it is not to be found in earlier writings, such as those of von Gruber. I can assure the members of my audience that do not teach that this confusion of coordinates with base components does not make the problem easier for students to understand. Having made this public protest, let me add that I have no more reason to suppose that any notice will be taken of it than I have to suppose that children will ever be taught an easier way of taking out square roots.

The instrumentation for the analytical method is included in Chapter X and the analogue instruments are described in two separate chapters: the projection instruments in XIII and those with mechanical or optical



AVERAGE Y PARALLAX  $\bar{P}_y = \frac{P_{y_U} + P_{y_M} + P_{y_O}}{3} = -\frac{3h^2 + 2d^2}{3h} d\omega$   
 $= -\bar{h} \cdot d\omega$   
 $db\gamma_{\omega_2} = +h \cdot d\omega_2$



$db\gamma_{\alpha_2} = -b \cdot d\alpha_1$

FIGURE 9-20. Quasisystematic  $db\gamma$  error.

trains in XIV. Third order instruments, including all those instruments in which the geometry is not rigorous, are to be found in Chapter XII. The direct projection plotter has been more highly developed in the United States than elsewhere and the authors of Chapter XIII have given us a really valuable review of the various forms of this category of instrument, and how it is constructed and how it is used. The authors of Chapter XIV have also given us a very remarkable review of the mechanical-optical instruments that have a rigorous geometry. The chapter is treated in historical lines but brings us right up to date with instruments made as recently as 1964. Whereas in the past the only serious

accounts have been essays by von Gruber and Sander in von Gruber's *Collected Lectures and Essays*, which has been sadly out of date for many years, now we have an equally authoritative article to which to refer. Chapter XII, on the non-rigorous instruments could, I suggest, have been greatly improved if we had been given the geometrical principles underlying the designs. Where a theory is not rigorous its errors are of the utmost importance and cannot be assessed if the principles are hidden away. This applies especially to the principle of the Zeiss Stereotope.

Chapters III and IV give us a very adequate summary of the optical principles that a photogrammetrist should know, though the



applications to mapping are confined to the direct projection plotters. What, however, strikes a European as remarkable is the absence of any discussion of the negative meniscus lenses that have been used so effectively to increase illumination at wide angles. The only reference, without any discussion of the important and interesting principle involved, is on page 93 where an uninformed reader would clearly gain the impression that the disadvantages outweigh the advantages. Objectives of this type have revolutionised mapping from air photographs; and whatever the explanation for the lack of emphasis on this type of objective in the *MANUAL*, one can only accept it as an example of how different things are on the other side of the Atlantic. This omission seemed even more striking to me when I later noticed that no less than 16 pages of Chapter IV (which is concerned with cameras) are given over to panoramic and other unconventional cameras which, so far as I know, have not been used in photogrammetry and, unless I am much mistaken, cannot yet be used to give the kind of precision easily obtainable with good conventional pictures in precision mapping equipment.

You will have noticed that I have not pursued a very regular course during this discussion; and I have done this partly to avoid the tedium of listing a regular catalogue of contents. I have, however, covered those parts of the *MANUAL* in which I have a special interest and to most of which I have tried to contribute something during the past 30 years. A great deal remains: some is administrative, some is technical and some speculative. So far as I am able to judge much of what is presented is use-

ful and all is interesting, though some of the omissions seem to be worth noting. In what appears to me to be a very thorough review of the photographic process (Chapter VI) I was surprised to find that the Modulation-Transfer Function, which seems to be occupying you so much in the United States, should be summarily dismissed in half a page; and there is no mention of color photography. Chapter XV, which deals very thoroughly with the automation of stereocompilation, is an extremely valuable addition to the literature, especially for people like myself who have had no first-hand knowledge of the developments; but I am sure we all expect to find a companion chapter on digital plotters and wonder why it is missing.

I have for many years been interested in stereoscopic perception and have some ideas on the subject, which I hope to develop when I retire or when someone leaves me a fortune. I would, therefore, like to make one general point in connection with Chapter XI on Stereoscopy. I have always wondered why writers on stereoscopic perception seem to be under the impression that a stereoscope invariably presents images to the eye so that a relief model is apparently seen at a near distance where relatively highly convergent rays intersect. In fact in all refined stereoscopes the rays are to all intents and purposes parallel and I look in vain for an author who will attempt to meet this. My point is illustrated by several diagrams in Chapter XI (e.g., Fig. 11-11), and, also, the somewhat (in my view) spurious hopter surface (Fig. 15-6) shown in Chapter XV on Automation for which, of course, Helmholtz and not the author is to be

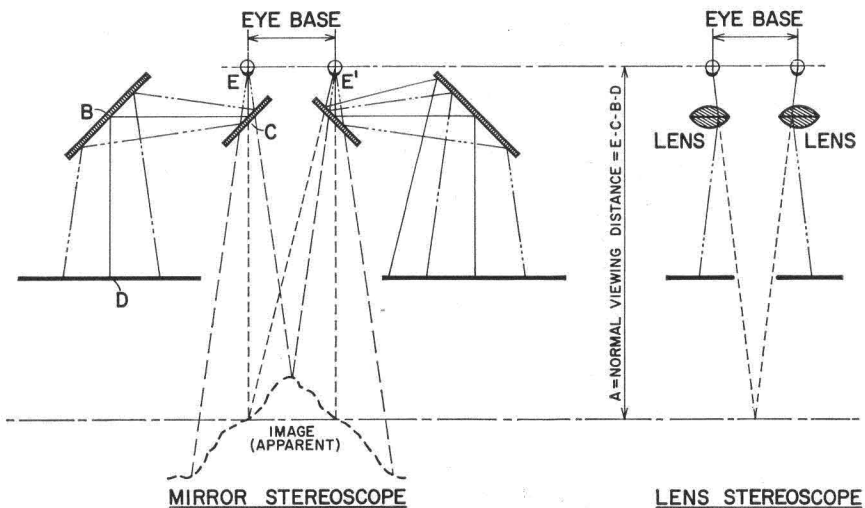


FIGURE 11-11. Helmholtz mirror stereoscope and lens stereoscope.

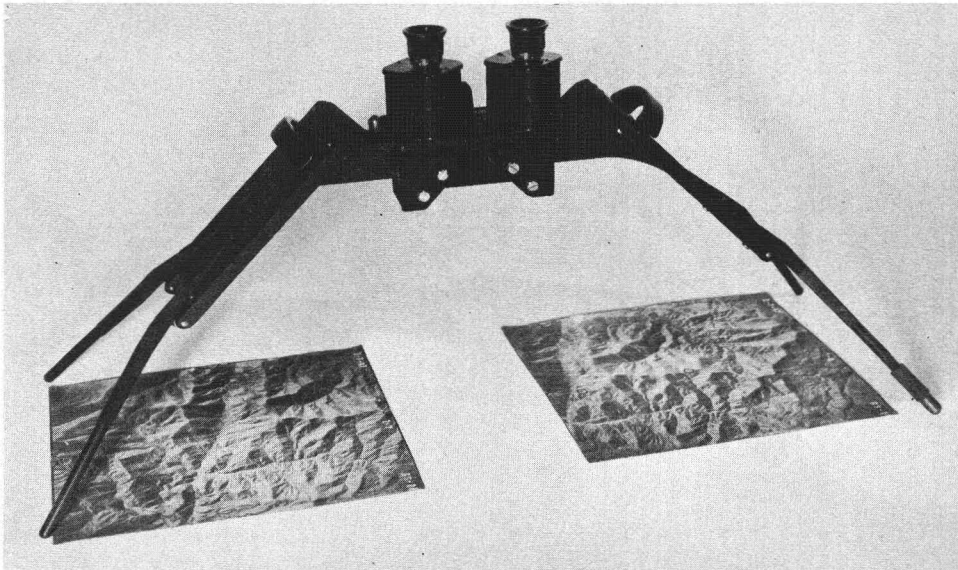


FIGURE 11-12. Fairchild F-71 stereoscope with binoculars.

blamed. The point to note is that authors always give us diagrams of the working of stereoscopes when the rays are convergent but fight shy of them and stick to photographs when the rays are parallel (e.g. Fig. 11-12).

The point I raise is, I think, more important than one of mere presentation. Stereoscopic perception, however necessary to the speed and accuracy with which we can carry out photogrammetric processes, and however valuable it may be in interpretation, has no geometrical significance. All operations in photogrammetry can be carried out monocularly, as indeed they were before 1900. The space model is a geometrical concept that is independent of what the observer perceives. My experience with students is that, what I would call the "space model" diagram in stereoscopy is extremely misleading and starts the beginner off along the wrong route.

I began this review by suggesting that a reviewer had two duties to perform: first to give you a summary of the contents, which I have interpreted to mean giving you a statement of what is missing; and, second, to examine what the book sets out to do and to say to what extent it falls short of this. I have, I think, said enough about the important omissions, which, if I may summarize, are failures to deal adequately with block adjustment procedures; to consider the principles and the implications of the analytical plotter; and to give a reasoned study of the basic geometry divorced from practice.

As I have said, the book sets out primarily to deal with up-to-date practice; and insofar

as this means North American practice I think it has admirably fulfilled its task. Two aspects of the up-to-dateness that I have not mentioned are Chapter XXI and Chapter XXII. The former considers the applications of photogrammetric techniques to pictorial data obtained by radar. I found the chapter

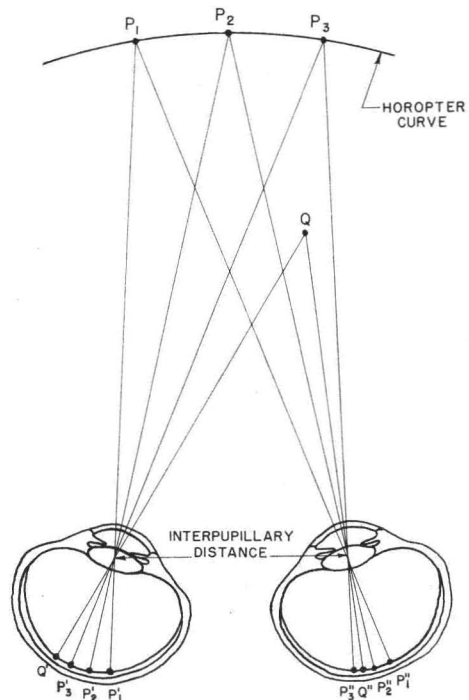


FIGURE 15-6. The horopter curve.

fascinating and while the authors are themselves on the defensive about the use of these methods, I think it is right that they should have been included—one never knows.

Chapter XXII deals with photogrammetry in the space age. The information in this chapter is relatively elementary and I think its chief value will not be to us but to those who design the spacecraft. We are at the moment studying the Ranger series of photographs in my laboratory with a view to obtaining metrical information. It struck me, as it has indeed struck other photogrammetrists, how very much more information we could obtain from these pictures if photogrammetric advice had been taken on the installation of the camera equipment. The inclusion of this chapter in the *MANUAL* gives us photogrammetrists an elementary and easily accessible account of the dynamic problems of space probes, but I hope it will do more. I hope it will, when taken in conjunction with the remainder of the book, persuade the spacecraft designers that we are people worth consulting.

While I am firmly convinced of the value of photographic satellites in Lunar and planetary mapping, I find it difficult to understand, and here I appear to differ from the authors of the chapter, how they can help us in the topographical mapping of the earth. On page 1086 there is a remarkable photograph (Fig. 22-37) of the Nile Delta taken by Astronaut McDivitt that would have brought joy to Ptolemy some 2000 years ago. What information does this give us that is not obtainable from a school atlas. The photographs of the moon and Mars are another matter.

Now let me say just a few words about the production. The paper, the typography, half-tone reproductions and diagrams are of the highest quality, and, what is very important, the binding will stand up to the weight. Good-looking books are sometimes deceptive. When you open them up there is a nasty cracking sound and they break in two. The *MANUAL* lies flat, almost of its own accord, at whatever page you open it. It is a credit to the editors.

When Morris Thompson asked me to review the *MANUAL* he said,

"The audience will expect criticism and we hope you will point out the shortcomings in a forthright manner."

I hope I have done what I was asked to do; and if I may make one overall forthright criticism for the improvement of a fourth edi-

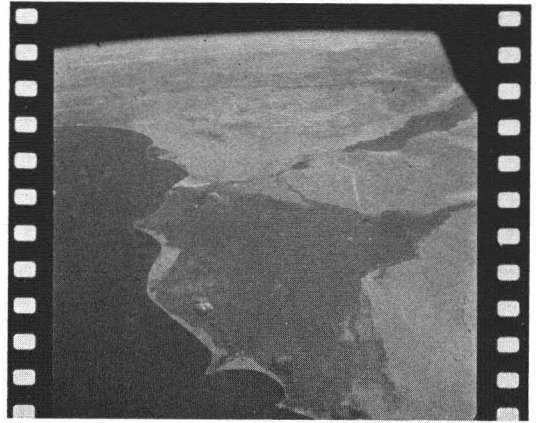


FIGURE 22-37. Actual-size contact print taken with Hasselblad 80-mm camera, hand-held by astronaut McDivitt. The Suez Canal can be seen connecting the Mediterranean Sea (lower left) and the Red Sea (upper right). The dark area (lower center) is the Nile River delta. (NASA photograph.)

tion, it is that much more attention be paid to separating the basic principles and mathematics from the practice. I do not think this impossible, but it would require very careful coordination and organization.

A review like this is bound to disappoint. You will see when you examine the *MANUAL* how impossible it would be to mention every chapter: there are twenty-five in all. This would be no disadvantage if the book had had one author: as it is, the careful and painstaking work of many of the contributors has not been mentioned. All I can say to those who appear to have been overlooked is that they have given me very little opportunity for adverse criticism.

In his letter Morris Thompson went on to say,

"We have enough confidence in the *MANUAL* to believe that its most ardent critics would not want to be without it, shortcomings and all."

I am quite sure that Morris Thompson was right. But I say this from hindsight: the *MANUAL* can be seen and we can have confidence in it, but those who planned this very expensive venture had to have faith. I, therefore, conclude my review with a tribute to the American Society of Photogrammetry and especially to those of its members personally involved for having had sufficient confidence to launch the venture and for having brought it to a highly successful conclusion which will benefit Photogrammetry the world over. I wish it the best of success.