*Increased Base : Height Ratio**†

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ABSTRACT: *This paper discusses the significance, background and present status of two methods of increasing the ratio of the photographic airbase to the flight height. The author supplies pertinent test results and defines the Army Map Service position in this controversial area. It is concluded that available test findings are not decisive and that additional controlled testing is mandatory before AMS can recommend any sweeping change in its present photographic geometry.*

I. INTRODUCTION

ONE of the goals of photogrammetrists everywhere is to devise means of increasing the altitude of the photographic aircraft without decreasing the accuracy of the map. In time of war such an increase is directly connected with survival. At all times, this goal is a significant economic consideration, because by doubling the altitude there is obtained four times the ground area. As one method of achieving this goal, there has been proposed an approach that increases the ratio of the distance between exposure stations to the altitude of the aircraft. Such an arrangement makes the angle of intersection of corresponding rays of a stereo model more obtuse, thus resulting in what an operator calls a "harder model." Several methods of obtaining this condition have been proposed over the years. Of these, the approaches that seem to have the most promise are convergent photography and the ultra wide-angle lens.

Convergent photography, for the purposes of this paper, is defined as that aerial photography taken simultaneously by two cameras whose axes are inclined toward each other in the line-of-flight by an equal and fixed amount. The ultra wide-angle lens is defined as having an angular coverage of approximately 120 degrees.

II. BACKGROUND

Neither the convergent nor the ultra wide-angle lens approach is new. Mr. R. Bosshardt, in the April 1957 issue of the *Schweizerische Zeitzchrift fuer Vermessung, Kulturtechnik und Photogrammetrie,* in an article entitled "Vertical or Convergent Photographs," states that convergent photography has been in existence for 30 years. Dr. K. Pestrecov, in an article entitled, "Notes on Russian Photogrammetric Optics," which appeared in the June 1954 issue of PHOTOGRAMMETRIC ENGINEERING, states that Mr. Rusinov applied for a patent to his 120 degree Russar lens in 1946. Mr. Bosshardt favors the convergent setup against the ultra wide-angle, and his paper appears to be primarily an answer to Professor Kasper's paper entitled, "Some Considerations on the Application of Photogrammetry for Small-Scale Cartography." The English version of this latter paper, which favors the ultra wide-angle lens approach against that of convergent photography, appeared in the December 1956 issue of PHOTOGRAMMETRIC ENGINEERING."

It is interesting to note that continental European photogrammetrists, prior to World War II, avoided the use of wide-angle cameras for precision mapping. They still do not use them in the convergent sense. In 1956 Zeiss Aerotopograph introduced a 210 mm. focal length, 180×180 mm. format convergent camera installation having a total angle of convergency of 27 degrees (13.5 degrees for each camera). This produces, under the 100 per cent forward lap system, a Base:Height ratio of

* Information contained in this treatise does not necessarily represent the official views of the Corps of Engineers or the Department of the Army.

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0.65, the same factor as that obtained by AMS with 93 degree vertical; 56 per cent forward lap photography. A possible advantage in the Zeiss convergent system is that the photography has a scale 1.37 times larger than standard 6 inch photography, at the isocenter.

Generally speaking, the optical projection type instruments, such as the Stereoplanigraph, Multiplex, Kelsh and Balplex, can accept convergent photography directly, with no modification. Instruments with a mechanical projection, such as the Wild equipment, cannot accept convergent photography without major optical modifications to rectify the images viewed, so that they will be identical in scale. Without this viewing rectification, the operator would see the convergent model exactly as he would view a pair of unrectified convergent photos with a hand stereoscope. Santoni, of Officine Galileo, has solved this problem in his Stereosimplex Model IIIb, with the necessary optical design which includes pancratic viewing. Convergent test results of this instrument have, to date, been unavailable to AMS. The 120 degree lens will require a completely new line of plotting equipment. It is understood that the Wild Company is designing an Autograph A-9 to utilize this super-Aviogon photography. It is emphasized here that test results are available only for convergent photography.

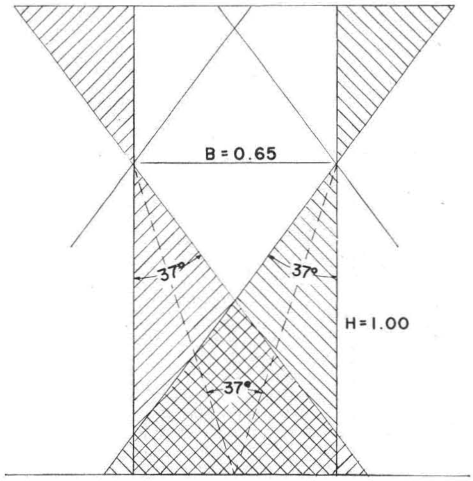

FIG. 1. Vertical model (wide angle).

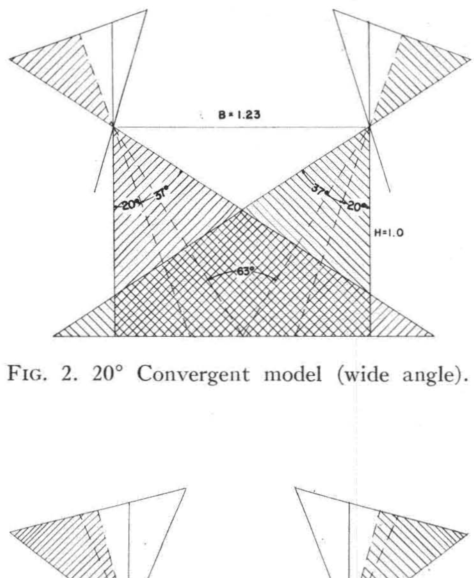

FIG. 2. 20° Convergent model (wide angle).

III. PHOTOGRAPHIC GEOMETRY

It seems appropriate to present a few diagrams and tables illustrating the geometry of the methods under discussion, mostly for the benefit of those whose activities have not caused them to be directly concerned with this subject. In Figures 1, 2 and 3, the focal-length is 153 mm.; the format is 230×230 mm. In Figure 4 the focal-length is 92 mm. and the format is 230×230 mm. The forward lap in Figures 1 and 4 is 56 per cent; in Figures 2 and 3, 100 per cent.

Table 1 compares the model factors of the four types of photography. The width-height ratio for convergent photography has been measured at the nadir line, which represents the minimum width of the usable model. The flight altitude squared can be multiplied by the area factors to give the net model coverage.

Table 2 shows the net model dimensions and areas under flight conditions which

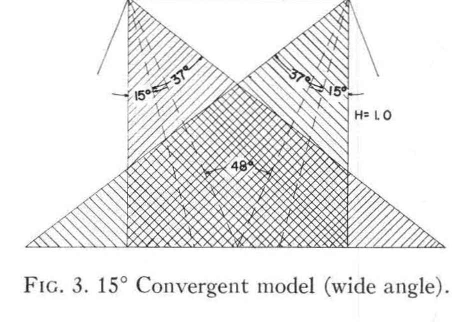

FIG. 3. 15° Convergent model (wide angle).

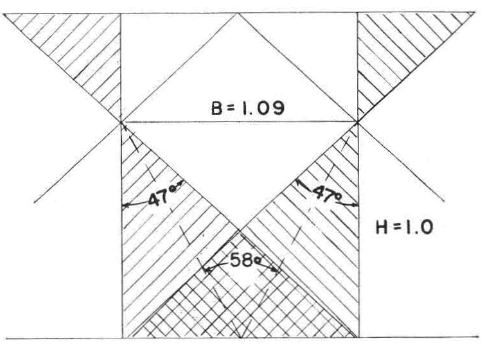

FIG. 4. Vertical model (ultra wide angle).

simulate an altitude of 20,000 feet. The base:height ratio times the altitude in miles gives the base of the model in miles. Correspondingly, the width-height ratio provides the width of the model, and the product of the two model dimensions gives the model area in square miles.

It is obvious from these diagrams and tables that the area covered by the 20 degree convergent model under equal altitude conditions is considerably greater than that covered by the similar camera under vertical conditions, and that the 15 degree convergent setup provides an area in-between. It is equally obvious that the ultra wide-angle camera, under the conditions given, provides considerably greater coverage than even the 20 degree convergent model.

IV. Test Results

The Army Map Service, over the past several years, has tested 20 degree convergent photography, relative to vertical, for compilation on the Kelsh and Balplex instruments. It has also made tests on the C-8 Stereoplanigraph for aerial triangulation. The Kelsh test figures were taken from AMS reports "Service Test of

TABLE 1

MODEL FACTORS

	1. *Vertical*	2. *20° Convergent*	3. *Ultra Wide-Angle*	4. *15° Convergent*
Base:Height Ratio	0.65	1.23	1.09	0.88
Width:Height Ratio (Nadir Line)	1.20	1.13	1.99	1.16
Area Factor	0.78	1.39	2.17	1.02

Side lap = 20%.
Vertical Forward Lap = 56%.
Convergent Forward Lap = 100%.
In all cases, camera format = 9″×9″.
In all cases except column 3, Lens = 93°; f = 153 mm.
In column 3, lens = 120°; f = 92 mm.

TABLE 2

MODEL DIMENSIONS AND AREAS: $h = 20{,}000'$

	1. *Vertical*	2. *20° Convergent*	3. *Ultra Wide-Angle*	4. *15° Convergent*
Model Base (mi.)	2.5	4.7	4.1	3.3
Model Width (mi.)	4.6	4.3	7.6	4.4
Area (square mi.)	11	20	31	15

$h = 20{,}000' = 3.8$ miles.
Side lap = 20%.
Vertical forward lap = 56%
Convergent forward lap = 100%.
All model dimensions are net.
In all cases, camera format = 9″×9″.
In all cases except Column 3, Lens = 93°, f = 153 mm.
In column 3, Lens = 120°, f = 92 mm.

TABLE 3

TERRAIN FLATNESS—SINGLE MODEL
20° CONVERGENT RESULTS COMPARED WITH VERTICAL

1. *Instrument*	2. *Number of Operators*		3. *Total Model Setup*		4. $h:RMSE_Z$	
	20°	*Vertical*	20°	*Vertical*	20°	*Vertical*
Kelsh	1	4	3	12	6,040	5,730
Balplex	4	4	12	12	4,830	4,121

Stereoplotter, Topographic, Projection Type, Kelsh," published in December 1955 and "Increased Base:Height Ratio for Aerial Photography," published in January 1957. The Stereoplanigraph aerial triangulation test figures were taken from the latter publication. Both of these reports were written by Mr. Jacob Halsey. The Balplex test figures were taken from AMS report, "Evaluation of Balplex Equipment," completed in July 1957. This was written by Mr. Donald Coulthart.

The compilation test photography was 6 inch Metrogon over Fort Sill, Oklahoma; it was taken at 30,000 feet for the convergent test and at 35,000 feet for the vertical test. The aerial triangulation test photography was 6 inch Metrogon over Phoenix, Arizona; it was taken at 30,000 feet for the convergent and at 20,000 feet for the vertical. The convergent angle of 20 degrees limited the Stereoplanigraph projection distance to 240 mm., thus severely restricting scale range of the instrument model. This aerial triangulation test resulted in a higher indicated accuracy of the vertical over the 20 degree convergent photography. The narrow base of the intermediate convergent model could have had some bearing on the accuracy results. For these reasons, the Corps of Engineers is about to investigate the potentials of 15 degree convergent photography. This proposed angle compares quite favorably with the 13.5 degree angle of the Zeiss convergent camera installation.

Table 3 presents terrain flatness data of single models, involving the Kelsh and Balplex type instruments. Except in the case of the 20 degree convergent Kelsh test, four operators were used. Each model was set up three independent times and each point read four consecutive times. Approximately 50 Geodetic Control points were used as the test standard. The ratios of the altitude to the root mean square errors of the z coordinate are shown in column 4. An average accuracy increase of 11 per cent is thus indicated for the 20 degree convergent over the vertical test photography in the z coordinate determination of individual points of a single model.

Table 4 shows contour compilation test results involving the Kelsh and Balplex type plotters. Again, except in the case of the 20 degree convergent Kelsh test, four operators were used. Two vertical models and one convergent model were compiled by each operator. The two vertical models covered approximately the same area as the one convergent model. Map profiles involving several hundred points were used as the standard of comparison. The ratios of the altitude to the root mean square errors of the contour profile points

TABLE 4

CONTOUR COMPILATION
20° CONVERGENT RESULTS COMPARED WITH VERTICAL

1. *Instrument*	2. *Number of Operators*		3. *Total Model Setup*		4. $h:RMSE_Z$		5. *Indicated C-Factor*	
	20°	*Vertical*	20°	*Vertical*	20°	*Vertical*	20°	*Vertical*
Kelsh	1	4	1	8	5,450	4,142	1,650	1,250
Balplex	4	4	4	8	4,498	3,684	1,360	1,100

TABLE 5

STRIP TRIANGULATION—C-8 STEREOPLANIGRAPH

	1. *Number of Operators*	2. *Altitude*	3. *Number of Models*	4. $h:RMSE_Z$
Vertical	1	20,000′	15	5,550
20° Convergent	1	30,000′	8	3,060

are shown in column 4. The indicated *C*-factors are shown in column 5. An average accuracy increase of 27 per cent for contours is thus indicated for the 20 degree convergent over the vertical test material.

Table 5 illustrates aerial triangulation test data involving the C-8 Stereoplanigraph. Column 4 shows the ratios of the altitude to the root mean square errors in the z coordinate. An increase in accuracy of the vertical over the 20 degree convergent strips of 81 per cent is thus indicated. Since only one operator and one instrument were used and the photography was taken at radically different altitudes, these results should be used very carefully.

V. DISCUSSION

That an increase in Base:Height ratio will produce a "harder model," thus resulting in increased accuracy of the determination of the Z coordinates of a single model, is beyond question. Just how much of an increase is obtained depends on whose test is being discussed. That either of the two primary approaches to obtaining this increased Base:Height ratio possesses all of the advantages is open to question. The convergent approach will have to contend with such things as: more hidden ground, increased processing and a rather dubious triangulation procedure. The ultra wide-angle lens approach will have to contend with a completely new line of plotting instruments and a decrease in photographic scale. The ultimate importance of all these factors is yet to be determined.

It should be emphasized here that if the accuracy resulting from convergent aerotriangulation is not consistent with that obtained in convergent compilation, the AMS use of this type of photography would be very limited. It is possible that the poor results obtained in the 20 degree convergent aerotriangulation test were due, in whole or in part, to as yet unrefined techniques in procuring and using the material. But it is believed by many that a reduction of the angle of convergency to about 15 degrees would result in stronger strip geometry.

With regard to the use of the ultra wide-angle camera, the most common objection is the reduced scale that would be afforded by a 92 mm. focal-length as compared to a 153 mm. focal-length. Regarding this, AMS conducted a small-scale comparative test of two aerial cameras exposed simultaneously over the Arizona Test area. One camera was on RC-5 film, 153 mm. focal-length, 230×230 mm. format; the other was an RC-7 plate, 100 mm. focal-length, 140×140 mm. format. The focal-length of the RC-7 plates was enlarged to 153 mm. in the U-3 printer. The corresponding models were set up on a C-8 Stereoplanigraph by several operators. The resulting accuracy, as determined by reference to given geodetic control, indicated a superiority of 10 to 20 per cent of the shorter focal-length camera. It is acknowledged that some of the increase in accuracy of the RC-7 camera might have been due to the superior stability of glass over film as an emulsion base. These test data, although limited, raise some doubt as to whether or not the vertical accuracy of the photogrammetric model will suffer appreciably by going from a 153 mm. lens to one of 92 mm.

Whether an increase in Base:Height ratio is more important than an increase in resolution is also debatable. The highest degree of z coordinate accuracy with which the author is familiar, concerned a Wild RC-7 camera; Aviotar lens, 170 mm. focal-length; 140×140 mm. format. The photography was flown at 9,000 feet over the Oberriet, Switzerland test area with an extremely low Base:Height ratio of 0.3-This model was oriented twice on an Auto. graph A-7 and read once on the Zeiss Stereocomparator by the same operator.

The average RMSEz was $h/10{,}000$.

To assist in arriving at some definite conclusions on this important but controversial subject, the Corps of Engineers is planning a series of significant investigations, with emphasis on aerial triangulation. The Research and Development Laboratories, Fort Belvoir, Virginia, has recently procured complete coverage of the Arizona Test Area with KC-1, Planigon lens, 6 inch focal-length cameras at an altitude of 10,000 feet. This coverage involves 20 degree convergent simultaneous with vertical photography and equal altitude 15 degree convergent photography. An analysis of these test data should provide significant additional information concerning the merits of the three types of photography.

VI. Conclusions

The test results to date are conflicting. Additional testing is mandatory before definite conclusions can be formulated, and this testing should obviously include 120 degree photography, as it becomes available. Undoubtedly, some as yet undiscovered proportioning of resolution, distortion, scale and Base:Height ratio will be the answer.

*The Significance of Reseau Photography in Triangulation Operations**†

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I. Introduction

In recent years, with the development of large capacity electronic computors, there has been a significant advancement of analytical aerial triangulation methods. Great strides have also been made in the development of a better photographic image with the manufacture of camera option, shutters, and platens nearing perfection. Similarly, such advancements have also been made in the precision of the measuring instruments until one believes that the ultimate has been reached. However, there is a third material link in the photogrammetric chain—that is the film. One might ask, "Have equal strides been made in the development of the film? Does the film truly record and preserve this record of image excellence to the same precision obtained with the aerial cameras and measuring instruments?" Even though there have been great improvements with aerial film, it is feared that the answers to these questions will be negative. Since it can hardly be expected that any more accuracy in the values obtained from the measuring instruments exists than in the film itself, there is an urgent need to do something about strengthening this link in the photogrammetric chain. Thus there will be provided an increased accuracy in aerial triangulation, an area where such is sorely needed. In several ways, the use of reseau photography would be of value in this critical area.

II. Background

Reseau, a word of French origin, means a network or a grid, and this grid superimposed upon film produces what is referred to as reseau photography. The first use of such photography may well be obscured in the volumes of publications and books on photogrammetry and its

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