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Automation at AMS

Stereoplotter, Analytic Aerial Triangulation, Analytical Hypsographic Compilation, LASER TPR, Earth Curvature Correction

(*Abstract on next page*)

Introduction

The foregone conclusion that we shall put a man on the moon by 1970 for $20 billion is terrifying testimony that modern technology can do almost anything—if the taxpayers are willing to pay the price. In the field of photogrammetry, if the prime consideration for complete automation were a matter of national pride, we probably could automate in the same length of time as getting to the moon for something less than that price.

Although the average taxpayer is intrigued by the moon and the rivalry involved in the race, he unfortunately never heard of photogrammetry—much less he couldn't even spell the word if he did hear it. Fortunately for the taxpayer, photogrammetric automation is generally proceeding along well-thought-out lines in the anticipation of tangible benefits. The main question is not, *can* it be done; rather, *should* it be done?

The purpose here is to: (a) state the peculiar needs of the Army Map Service (AMS) and the consequent approach in launching photogrammetric automation projects, (b) outline some of our recent experiences, (c) discuss some of our immediate plans, and (d) offer general appraisals based primarily on our needs, experiences, and plans.

Requirements and Approach

At the core of our requirements is the fact that AMS is not a "fair-weather" mapping agency. Our job is to provide the ground forces with the maps and map substitutes necessary to get the job done. The need of the ground forces for these products stops neither when night falls nor when the weather is bad. AMS's mapping capability, therefore, must be an all-weather, around-the-clock operations, which includes the ability to make the best use, in a "crash" manner, of material that never was intended to be used for mapping. Equipment and methods must be as universal and limitation-free as possible. Such mapping operates on the premise that a map having an accuracy of 20 meters, delivered on time, is far more useful than one good to 2 meters delivered too late.

Finally, because it is necessary to map in enemy areas, the material procurement system is aimed at a self-contained operation that gives us all the materials and positional information we need to produce a map.

In short, AMS needs a system that is all-weather and around-the-clock, with capabilities of maximum input/output, calendar speed, and being self-contained. Automation

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ABSTRACT: *The Army Map Service (AMS) needs a system that is all-weather and around-the-clock, with capabilities of maximum input/output, calendar speed, and being self-contained. Automation is playing a key role in satisfying these needs. AMS has had recent experience with the Stereomated Aviograph B-8, Analytical Aerial Triangulation, Analytical Hypsographic Compliation, the LASER Terrain Profile Recorder, and an Electronic Earth Curvature Correction Device. Looking into the immediate future, further investigation is planned on Analytical Aerial Triangulation, the Stereomat, the LASER Terrain Profile Recorder, and Digitizing Stereocompilation. Appraisals are based primarily on the AMS needs, findings, and plans.*

is playing a key role in helping attain such a system.

Due to the foregoing requirements, AMS will always have "exotic" as well as conventional equipment. Any automation in the conventional area must be economically justified in some tangible way as an increase in needed accuracy or efficiency. For example, we still find the Multiplex to be the most efficient means of satisfying our normal 1:250,000-scale mapping requirements.

As most of you know, in the Army Corps of Engineers the long-range research and development in the field is conducted by the Geodesy, Intelligence and Mapping Research and Development Agency (GIMRADA) at Fort Belvoir, Virginia. As part of its mission, however, AMS maintains an aggressive product-improvement program. We are continually analyzing our current prodceures, equipment, and materials against production needs and the state-of-the-art. Should an AMS investigation result in a development contract, however, the matter is turned over to GIMRADA.

SELECTED AMS AUTOMATION PROJECTS

A summary of recent activity and/or immediate plans, concerned with photogrammetric automation, includes reports on:

- The Stereomat
- Analytical aerial triangulation
- Analytical hypsographic compilation
- The LASAR terrain profile recorder
- Digitizing stereocompilation
- An electronic earth-curvature correction device.

Each item is concluded with an appraisal based primarily on AMS needs, findings, and plans.

STEREOMAT IV (AUTOMATIC STEREOPLOTTER) RECENT ACTIVITY

The Stereomat IV was built by Hunting Surveys, Ltd., Toronto, Canada, from the concept of Gilbert L. Hobrough, and delivered to AMS by the Autometric Operations, Raytheon Company, after the March 1964 ASP-ACSM Annual Convention. The testing was performed in three phases: grid, terrain model flatness, and contouring. Mr. Charles Lawrence, my AMS colleague, recently presented the details of his work on this subject.[1] A summary of results by phase is as follows:

Grids. The vertical standard errors, in terms of the projection distance are shown in Table 1.

Terrain model flatness. The vertical standard errors in terms of the altitude h were: $h/5000$ manually; $h/5600$ automatically. (Previous testing using the same photography obtained $h/6000$ for the conventional AMS M-2 Stereoplotter.)

Contouring. Although inconclusive, the results of this contouring were disappointing. They do not appear to be in line with the Stereomat's ability to determine the elevations of individual points. We must perform further analysis before we can be more specific.

General findings, pertaining to the topic of Stereomat contouring, are as follows: (a) the contouring speed of the Stereomat is superior to that of an operator on the M-2 by a factor of about 2, depending on the model characteristics, i.e., the extent of areas of poor image correlation caused by extremely steep slopes (30 degrees or more), flat areas (less than 3 degrees slope), or lack of detail; and (b) there is a significant deterioration of contour accuracy in drainage turnbacks, and on

TABLE I

Mode	*Projection Distance (mm)*		
	213	*262*	*311*
Manual	1/11,200	1/11,900	1/7,600
Automatic	No Correlation	1/20,700	1/10,000

sharp ridge lines. It is expected that these deficiencies will be largely overcome in later Stereomat models.

IMMEDIATE PLANS

In the course of our test and analysis of two Stereomat configurations, AMS has made many recommendations for the improvement of the system. Many of these have been incorporated in later models, especially the Stereomat V. This latter model is also incorporated in the Wild B-8 Aviograph, but includes the capability of digitizing coordinates during the orthophotographic step. The output of this system will be quite similar to that proposed by AMS in 1957 and called the "Integrated Mapping System."[2]

We recently completed a set of technical characteristics for our version of a "Stereomated Automatic Stereoplotter":

a. *Input*. To accept either wide- or superwide-angle photography, in a format up to 9×9 inches.

b. *Orientation*. To establish relative orientation in 10 minutes with maximum residual y-parallax of 8μ at plate scale. Automatic absolute orientation may be provided, but access for manual intervention is essential.

c. *Orthophotos (values referred to plate scale)*. To produce orthophotos with a minimum resolution of 20 lines/mm, with detail positioned to 60μ, in a maximum of three hours.

d. *Contours*. To provide for manual and automatic continuous line contours, and also automatic line-drop contour information and recorded hypsographic coordinates produced simultaneously with the orthophoto to a minimum C-factor of 1,000; the automatic continuous line contouring to be accomplished at the rate of 4 to 6 hours per model.

APPRAISAL

In addition to hastening significantly the stereocompilation process, the proposed system will provide orthophotographs and taped hypsography in a matter of three hours. The orthophotograph is a correct planimetric map. The tape can be fed directly to an automatic model carving system, or to a line-plotter to produce a contour overlay for the orthophotograph. In the more conventional sense, copies of the orthophotograph would be given to several cartographers, while copies of the contour and drainage manuscript would be given to yet other cartographers, thus significantly reducing calendar time.

Analytical Aerial Triangulation

RECENT ACTIVITY

In this area, we are collaborating with GIMRADA and also doing some work (modification of shelf items) on our own. We have been using analytical photogrammetry to produce single models for almost a year. This work started with single models of Ranger VIII moon photography because our analog equipment, at that time, could not accommodate the geometry.

Our main effort in the analytical area centers on the Schmid method, and involves: programming for the Honeywell-800 computer; absolute evaluation in wide-angle, superwide-angle and, if possible, convergent modes; and comparison with current AMS aerial triangulation production techniques to determine the relative accuracy, speed and economy of the overall system.

The status of this project is that: the single camera and the single model programs are operational, and the general strip has been studied and the mathematics worked out, under Dr. H.H. Schmid's direction, by the Army's Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland. It is now a matter of "systems analysis" to determine precisely what the strip should do and the most efficient way of doing it. Completion of strip programming has been estimated for the end of this year.

Relative orientation of Ranger stereomodels could be achieved in the Stereoplanigraph; but, due to physical range limitations of the instrument, absolute orientation could not be achieved. Therefore, GETRAN, acronym for *GE*neral *TRAN*sformation, as introduced by Professor von Gruber, was programmed out of a need to continue where the Stereoplanigraph left off in order to achieve absolute orientation of the x, y, z-coordinates.[3] GETRAN is a completely general program for a rigorous least-squares transformation of one orthogonal coordinate system to another, incorporating the curvature of the defined spheroid, and placing its output in the Mercator projection. GETRAN is coded in Fortran IV programming language for the Honeywell-800 computer.

IMMEDIATE PLANS

In addition to completing our evaluation of the Schmid method, at least through the strip, we are collaborating with GIMRADA in the rigorous testing and evaluation of two analytical aerial triangulation programs developed under GIMRADA contracts: SIMBAT and MUSAT. Both of these systems were programmed under GIMRADA contracts with the Autometric Operation of Raytheon Company for the IBM 7094 computer.

SIMBAT, the acronym for Sequential Independent Model Block Analytical Triangulation, is based on the work of G. H. Schut of the National Research Council of Canada.

MUSAT, acronym for Multiple Station Analytical Triangulation Program, was designed to combine features of the Herget, Brown, and Schmid formulations.

The evaluation project will include the following general procedures:

a. Each program will be tested with fictitious data generated by the "GIMRADA Fictitious Data Generator Program" prior to testing with real data. This will provide a period of familiarization with each program, and also debugging and modification, as required.

b. The photography will be taken with the distortion-free KC-4 (Baker lens) cartographic camera flown at 30,000 feet over the entire Phoenix, Arizona Test Area. This will provide an area, for the largest block, of at least 1,000 square miles, involving some 100 stereo models.

c. The single exposure, the single model, the strip, and the block will be measured and evaluated. All material will be measured on a Zeiss Stereocomparator (PSK). Measurements of the model and of the strip will be repeated on a Zeiss C-8 Stereoplanigraph. In all cases, three independent orientations will be made.

d. A variety of adjustment configurations will be used for both the strip and the block.

APPRAISAL

Literally, a mountain of technical papers has been written over the past 15 years pertaining to analytical aerial triangulation. We have recently compiled a bibliography which lists 72 published texts in the English language alone.

The great bulk of this literature shows how to make this new tool, analytical aerial triangulation, or how to use it. An extremely small portion of this literature provides comparative results to form a basis for determining when, and when not, to use this tool. Such conclusions should be based on over-all considerations of the crucial factors of accuracy, cost, and time.

According to the information studied by Dr. Ackermann[4] the comparison between analog and analytical methods ranges from the analog being slightly better to the analytical being three times better. Then, Dr. Gotthardt[5] recently concluded that a 20 to 40 per cent increase in accuracy over conventional analog methods is the most that can be expected from analytical procedures.

Although there is some disagreement regarding the degree, it has been definitely established that analytical aerial triangulation is more accurate under ideal conditions. But, exactly where is the cut-off point where conditions are no longer sufficiently ideal? Are there enough rigorously controlled, user, test data available which compare the various analogical and semi-mathematical approaches to the analytical to determine relative time and cost? We don't think so, and we are getting our own data to supplement the findings of others. It may be of note here that private contractors bid higher on a given aerial triangulation project to do it analytically than they do for an analogical solution.

The foregoing, however, concerns only the *extent* to which AMS will use analytical aerial triangulation. We are using it and shall increasingly use it to perform work that just cannot be done any other way. We consider that analytical photogrammetry offers us a new and powerful tool whose only limitation is the size of the plate that the comparator can accept.

Analytical Hypsographic Compilation

RECENT ACTIVITY

This is a system we put together from shelf parts in order to produce hypsographic compilations of the moon from Ranger photography as our analog stereoplotting equipment could not accommodate the material at the time. This system uses coordinates from either the GETRAN or the Schmid methods. This method was described by my colleague, Donald L. Light,[6] at the 1965 ASP-ACSM annual convention.

In essence, networks (1 mm. interval) of x, y-Sterocomparator coordinates, or x, y, z-Stereoplanigraph coordinates, were recorded from the Ranger stereomodels. These coordinates were then abolutely adjusted to the selenodetic control; the Stereocomparator coordinates by the AMS version of the Schmid method; and the Stereoplanigraph coordinates by the GETRAN method. (The outputs of both Schmid program and the GETRAN program are directly in a compatible form for analytical hypsographic compilation.) A computer contouring program of Control Data Corporation was then employed to interpolate contours from the adjusted points. The contours were drawn by a California Computer Products, Inc., (CALCOMP), drum-type X, Y-plotter by the Control Data Corporation. (We now have our own CALCOMP plotter.)

Since the presentation of Mr. Light's paper, some interesting comparative vertical information has been produced by our photogrammetric lunar team and compiled by my colleague, Lawrence D. Bowles. This was a

TABLE II. Z-COORDINATE DETERMINATION (METERS)

Point ID	Control	GETRAN Program	Schmid Method	Conventional
	Z	Δz	Δz	Δz
R9	368.442	−0.17	+0.74	−0.16
T9	359.877	−0.80	−0.73	−0.16
U9	359.755	−0.56	−0.76	−0.16
S8	354.940	−0.10	+0.04	−0.16
T8	355.670	+0.33	+0.26	−0.16
R7	347,045	+0.22	−0.69	−0.16
S7	349.971	+1.11	+0.17	+1.84
U7	357.317	−0.46	+0.06	−0.16
S6	349.392	+1.32	+0.76	−0.17
T6	353.995	+1.30	+1.54	+1.84
U6	358.323	−0.28	−0.20	−0.17
R5	345.674	−0.11	−0.17	−0.17
R4	356.250	−2.91	−1.27	−2.56
S4B	367.955	+0.95	+0.60	−0.16
T4	404.043	+1.70	+0.11	+1.84
U4	367.833	−1.54	−0.46	−1.17
Standard Error (σ_z)		1.18 (h/6,400)	0.70 (h/10,900)	1.11 (h/6,800

comparative analysis of Z-coordinate determinations, as derived by the two analytical approaches (the GETRAN Program and the AMS/Schmid Analytical Method), with data derived by conventional analog procedures using the Stereoplanigraph. The photography was taken by a KC-lb, distortion-free, cartographic camera, 6-inch focal length, flown at 25,000 feet over the Phoenix, Arizona Test Area. The coordinates for the GETRAN Program were measured on a Stereoplanigraph C-8 with the model relatively oriented. This model was oriented with maximum tip (ϕ) in order to duplicate, in so far as possible, the Ranger camera's exposure attitude. The coordinates for the Schmid method were measured from the same plates on a Zeiss Stereocomparator (PSK). A different Stereoplanigraph C-8, and a different set of plates, were used for the conventional procedure. One operator made one orientation in each of the three methods. Three successive observations per point were made on the C-8; five on the PSK. In all cases, a best vertical fit was obtained to 16 given points. The results are shown in Table II.

APPRAISAL

For the present, this must be considered a special-purpose tool which can produce needed hypsographic information from materials that are beyond the accommodation ranges of available stereoplotters. Even so, more study is needed to provide guides for the selection of the proper profile interval. Also, the program used by AMS needs additional safety features built in so that measuring blunders will be rejected. At present, a blunder will result in a mountain or a depression where there is not supposed to be one. The prototype system will do this without so much as a twitch of an electronic eyelash.

The additional knowledge and safeguards can be developed, of course, but then, there is the matter of speed. A typical case would be to establish coordinates of points at half-millimeter intervals at plate scale. Now, an average AMS model at plate scale is 100 by 180 mm. We would have 72,000 points to observe. Taking 3 to 5 observations per point would require, on the average, 1.5 minutes per point, or, 108,000 minutes (1,800 hours) per stereomodel.

The fact remains, though, that analytical hypsographic compilation is an additional tool. If the problem can be measured on a comparator, and analytically oriented, then the contours can be analytically interpolated and automatically drawn. A radical increase in measuring speed would open up new horizons for the method.

LASER TERRAIN PROFILE RECORDER

RECENT ACTIVITY

A continuous-wave helium-neon gas LASER Terrain Profile Recorder has been developed by Spectra-Physics, Inc., Mountain View, Calif., and Aero Service Corp., Philadelphia, Pa.[7] Aero Service has tested it for over-all functioning at altitudes ranging from 500 to 15,000 feet above terrain, producing profile data with excellent resolution.

This high resolution, relative to that obtained with the Airborne Profile Recorder (APR), is due to the fact that LASER TPR emits a single pencil-beam of parallel light; whereas, the APR beam is a cone of 1.5 degrees. At our operational altitude of 30,000 feet, the APR cone covers an area of about five acres. APR, then, gives a roughly average value for that area; whereas, at the same altitude, the LASER beam covers an area of less than one square foot.

My colleague, William H. Schwieder, observed a test run in the vicinity of Allentown, Pa., in September 1965 from an altitude of 2,000 feet. Aero Service gave AMS a set of the resulting data for analysis: the LASER profiles, the 35-millimeter spotting camera photography, the Wild RC-8 mapping photography, and the existing map coverage.

The results of the AMS analysis of these preliminary data confirmed the excellent resolution and relative accuracy capabilities of the LASER TPR. Some of the findings are as follows:

a. A light pole was identified at a road intersection and measured to be 30 feet in height.

b. The actual shapes of individual trees and buildings were portrayed. In dense tree growth the ground elevation could be determined wherever the beam hit an opening in the foliage of a foot or more in diameter.

c. As the beam passed over a cornfield, each row of corn was shown. The height of the corn was determined to be between 7 and 8 feet.

The results of this test showed conclusively that LASER TPR has much to offer the AMS mapping effort. The item of primary concern now is absolute accuracy. We drew up plans for a comprehensive evaluation program over controlled test areas.

IMMEDIATE PLANS

A contract with Aero Service Corporation to provide AMS with the LASER test data over the Phoenix Test Area has recently been signed.

The objectives of this program are to determine:

a. The capability of the LASER Profiler to provide vertical control over various types of terrain, using long and short profiles.

b. The density and distribution of LASER TPR control required to achieve optimum accuracies in setting individual stereomodels and in stereo bridging.

c. The effects of attitude and altitude deviations on the LASER TPR measurements made with the fixed mount configuration.

d. The effects of the airborne datum, and deviations therefrom, on LASER-determined ground elevations, using long lines of aerial photography and long profile lines flown independently at various altitudes.

The immediate agenda is as follows:

a. Prior to proceeding with the Phoenix Test, certain operations will be performed by Aero Service at the North Philadelphia airport. These will consist of ground and airborne calibration tests, airborne range tests, and data handling procedures. At the time, AMS personnel will be at Aero Service to assist in formulating the monitoring and inspection procedures to be used in Phoenix.

b. The Phoenix tests will involve five lines of precision mapping photography flown over selected areas. Two hundred linear miles of conventional photography will be flown at 30,000 feet with the distortion-free, KC-4 camera. The subsequent LASER profiles (8 to 10) will be 200 miles long and will be flown at various altitudes on different days. The photography, profile data, and associated materials will be monitored and inspected on site by AMS personnel. All data reduction will be performed at AMS.

c. Bridging tests and single model tests will be performed with the profile data. The LASER TPR data will be analyzed for fidelity and anomalies in the recorded data and accuracy of the profile data over various types of terrain, including desert, mountain, forest, and urban areas.

d. The results of the Phoenix tests will provide information for planning additional tests, at a later date, of very long lines over rugged terrain in southern California.

APPRAISAL

AMS considers the LASER Terrain Profile Recorder to be a breakthrough in the acquisition of airborne control. *Fantastic* is the only word that I can think of to describe adequately its resolution capabilities. The big question is how well this relative information can be coordinated to the airborne datum to produce absolute vertical control. Although the system being studied presently has a ceiling in the order of 20,000 feet, for much of our work the profile data could be obtained before or after the mapping photography, and at whatever altitude would best suit the TPR.

Identification with the LASER TPR is much more positive than with the area delineation of APR. Also, if the results of further testing are as good as anticipated, using simultaneous mapping photography with 60 per cent side lap, LASER could satisfy much of our small- and medium-scale requirements for vertical control. Then the successful incorporation of SHIRAN for horizontal control could eliminate aerial triangulation as a separate mensuration exercise for much of our work.

Digitizing Stereocompilation

Recent Activity

As reported at the 1965 and 1966 ASP-ACSM annual meetings[8,9], AMS has been trying to satisfy the need for furnishing topographic information in digital form on rolls of magnetic tape. This involves digitizing the topography that has been previously plotted on the map. A recent need is for topographic information picked up while the map is being compiled. Consequently we have just launched an in-house investigation, "Digitizing with Stereophotogrammetric Plotting Instruments," the objectives of which are:

a. To determine the feasibility of digitizing map data from manual stereophotogrammetric instruments simultaneously with the stereocompilation process.
b. Contingent on results of the feasibility study, to determine optimum hardware and methods.
c. To analyze the results for possible further application in such areas as: map revision, color separation, and intelligence.
d. To familiarize production personnel with various trends and possibilities of automation.

Immediate Plans

To reduce costs during the feasibility stage, to expedite the testing, and to provide more rigorous data for analysis, this work will be done on a digitized, presently available, Stereoplanigraph C-5, the Stereomat, and the Nistri Comparator paper-tape punch. All that is missing is an automatic means of triggering coordinate recordings at discrete intervals of X and Y during a profiling process. Our supporting personnel are making this triggering device in-house.

Our efforts to determine optimum methodology will include studies of such areas as:

a. Hypsographic compilation approach: contour or profile scanning.
b. Compilation procedures for recording drainage, culture, vegetation, and miscellaneous features.
c. Procedures in the matching of models, plot sheets, and/or sheet quads.
d. Number and types of symbols needed in the digitizing of a topographic map.
e. Displacement procedures due to size and position of symbols.
f. Generalization and elimination procedures due to overcrowding of detail.

Appraisal

This work is essentially study and experimentation. We know that other work is under way to completely digitize the stereocompilation step so as to render it fully automatic. Based on our experience, however, we believe that it will be some time before such a system is fully operational.

Mr. U. V. Helava, inventor of the Analytical Plotter, states that there are four major steps in "automatic image analysis."

a. "Automatic image correlation (finding corresponding points on two photographs).
b. "Automatic identification of details (finding image details with specific characteristics).
c. "Automatic photointerpretation (finding what an image detail is in reality).
d. "Automatic image intelligence (finding what the details mean)."

"At the moment we are struggling with the problems of the first stage. Great progress has been made, but I am not at all convinced that we know what we are doing. To me, there is an appalling lack of scientific studies in this area."[10]

Mr. Helava was speaking from the instrument designer's point of view. There are many questions from the user's side, that also need answers. Some of these questions are:

a. What is the best contouring approach? Continuous line or profile scanning? Has anyone rigorously compared the two modes? (i.e., what is best for the user, as opposed to what is more feasible for the manufacturer)?
b. To what extent can we reduce the number and types of our map symbols? This decision must be made in conjunction with the users of our maps. Cutting the number of symbols down to make a system possible to build accomplishes nothing if the users' needs are not met.
c. To what extent will our symbol generalization, displacement, and elimination procedures have to be modified in a digitized system?

We are confident that the results of our study and experiment will not only help guide manufacturers, but will also open new vistas, and will certainly better prepare us to implement the new digital compilation systems.

Electronic Earth Curvature Correction Device

Recent Activity

In 1964, AMS designed and built, in-house, a prototype electronic device to compensate for earth curvature in the AMS M-2 Stereoplotter. Extensive testing was performed at various scales and radial increments, in the conventional model mode, and also, via profiles. During this testing, no error exceeded 0.05 mm., which at M-2 plate scale is 0.01 mm.

During the shakedown and testing, however, two major problems were encountered:

a. Any rotary motion of the tracing table during operation produced an undesired correction signal. The AMS tests, therefore, used a

T-square arrangement to maintain the tracing table in a plane parallel to the front edge of the granite drawing surface. This undesirable feature is noted in the purchase description, presently out for bid, and proposals will provide for minimum of ±30 degrees of error-free rotation.

b. There was a tendency of the correction motor to impart motion to the counter of the tracing table. This problem has been solved in-house and the improvement is also a part of current contract negotiations.

APPRAISAL

Although of small interest to theoreticians, this item is of great concern to those organizations that have to compile topography from photography taken at altitudes where the curvature of the earth is measurable. This device has the accuracy of the optical and mechanical devices without their serious drawbacks. For example, both the optical and mechanical methods require a battery of compensating plates, or cams, for various altitudes. The cams, moreover, are susceptible to wear. Although designed for the Kelsh-type plotter, we see no reason why the AMS principle cannot be applied to any conventional stereoplotter.

Conclusion

The projects discussed in this article comprise the heart of the photogrammetric process—aerial triangulation, and stereocompilation. The work is completely user-oriented, and its main purpose is to increase AMS's ability to supply the best possible information in whatever form the user needs, and from whatever source material is available. The rigor and universality of the mathematical formulas, the untapped wonders of the LASER, and the speed and capacity of the electronic computer, are daily helping AMS to accomplish its mission better.

References

1. Lawrence, Charles H., "Stereomat IV, Automatic Plotter," Photogrammetric Engineering, Vol. XXXIII, No. 4, pp. 394–402, April 1967.
2. Spooner, C. S., Dossi, S. W., and Misulia, M. G. "Lets Go Over the Hill," Photogrammetric Engineering. Dec. 1957: Vol XXV, No. 5.
3. von Gruber, Otto, *Photogrammetry, Collected Lectures and Essays*. Boston: American Publishing Company, 1942.
4. Ackermann, Dipl.-Ing. F. "Die Heutige Lage in der Analytischen Photogrammetrie," *Bildmessung und Luftbildwesen*. 1963: Special Issue.
5. Gotthardt, Dr.-Ing. E. "The Present Status of Analytical Photogrammetry." 30th Photogrammetric Weeks, Karlsruhe, Germany. Sept–Oct 1965.
6. Light, Donald L. "Ranger Mapping by Analytical Topographic Compilation," Photogrammetric Engineering, Vol. XXXII, No. 5, pp. 792–800, September 1966.
7. Jensen, Homer and Ruddock, K. A. "Applications of a LASER Profiler to Photogrammetric Problems." Presented to the ASPACSM Annual Meeting, Washington, D. C. March 1966.
8. Mays, R. R., Noma, A. A., and Aumen, W. C. "Digitizing Graphic Data at the Army Map Service." Presented to the ASP-ACSM Annual Meeting, Washington, D. C. March 1965.
9. Aumen, W. C. "A New Map—The Numerical Map." Presented to the ASP-ACSM Annual Meeting, Washington, D. C. March 1966.
10. Helava, U. V. "Theoretical Aspects of Automation in Photogrammetry." International Society of Photogrammetry Symposium of Commission II, "Automation in Photogrammetry—Aims and Limitations." Bad Godesberg, Germany. April 1966.

Selected Bibliography

Beck, W. "Das Kartenbild der Landschaft: Möglichkeiten und Grenzen der Automation Seiner Herstellung." *Zeitschrift für Vermessungswesen*. 1965: Special Issue.

Bonneval, Ing. H. "Aims and Limits of the Automation in Photogrammetry." International Society of Photogrammetry Symposium of Commission II, "Automation in Photogrammetry—Aims and Limitations." Bad Godesberg, Germany. Apr. 1966.

Makarovic, Dr. B. "Some Fundamental Considerations on Automation in Stereo Restitution." *Ibid.*

Schermerhorn, Prof. Dr. W. "Wohin Führen Photogrammetrie und Automatisierung das Vermessungswesen?". *Osterreichische Zeitschrift für Vermessungswesen*. 1965: Vol 53, No. 6.

Schwidefsky, Prof. Dr. K. "Aspects of Designers and Producers of Photogrammetric Instruments." International Society of Photogrammetry Symposium of Commission II, Automation in Photogrammetry—Aims and Limitations." Bad Godesberg, Germany. Apr. 1966.

Schwidefsky, Prof. Dr. K. "Die Grenzen von Mensch und Automat in Photogrammetrie." Karlsruhe, Germany. Nov 1963.

Wunderlich, W. "Grossmassstäbige Photogrammetrie—Lage und Ausblicke," *Zeitschrift für Vermessungswesen*. 1965: Special Issue.

See announcement of 1968 Congress in Switzerland on page 658.