*The Photogrammetric Improvement Program of the Army Map Service**

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ABSTRACT: *In describing the AMS photogrammetric improvement program, the following aspects are touched upon: general policy and objectives, production tie-in, relationship with other organizations, present program and recent findings, and future program.*

INTRODUCTION

THE primary function of the Army Map Service, as one could suspect, is to make maps. This, of course, does not necessarily mean use of the same procedures, equipment, and materials, decade after decade until change is requested by higher echelons. Such would be an impossible situation, completely stifling all initiative of the people who are making the maps and who know from their day by day experience when a change would result in a better product, faster and at less cost to the tax-payer.

These basic facts of life have fortunately been recognized, and the improvement efforts of AMS have been given every encouragement by the Office of the Chief of Engineers. As part of its mission, therefore, the Map Service maintains an aggressive product improvement program. Current procedures, equipment, and materials are continually analyzed against need and the state-of-the-art.

The purpose of this paper is to: 1) present our general policy and objectives, 2) show the tie-in with the production elements, 3) discuss our relationship with outside, related organizations, 4) summarize the present program, 5) cite some recent findings, and 6) give a preview of some anticipated work.

GENERAL POLICY

The general policy of this improvement program is threefold: 1) to insist on a clear definition of need, 2) to place emphasis on those investigations which show promise of a substantial improvement early in the Cartographic chain, thus benefitting subsequent procedures, and 3) to effect technical improvements, whenever possible, as part of the operating element's production assignments.

Underlying all of our activity, is the determination to give our customers (the map users) what they need. We do not wait for them to come to us. We go to them. Questionnaire and conference-type surveys are continually conducted with the users to determine the acceptability of AMS products, and, it should be noted, quite often the map users offer valuable suggestions for map improvement. Moreover, we constantly evaluate research and development activities in military techniques, equipment and weapons to anticipate future needs for military maps and geodetic support.

GENERAL OBJECTIVES

In general, the objectives of this improvement program are the same as those of any other large mapping agency. In addition, however, the needs of military mapping dictate other objectives that are especially vital in times of emergency.

The rather universal objectives, more or less interrelated, would be such as: 1) increasing the size of the photographic "bite" while maintaining accuracy, 2) employing automation where advantages are proven, 3) gathering information as a basis for planning and procurement, and 4) educating production personnel in new procedures.

Some objectives, peculiar to the needs of military mapping, are 1) to reduce dependency on ground control, 2) to increase production capability and flexibility, 3) to reduce calendar time (a system where raw

* Presented at the Semi-Annual Meeting of the American Society of Photogrammetry, Wellesley Island, New York, 12–14 September 1963.

The information contained herein does not necessarily represent the official views of the Corps of Engineers or the Department of the Army.

materials can be gathered at one point and simultaneously given to a number of operations).

Production Tie-in

It is the policy of the Army Map Service to instill, in each employee, the desire, and, in each supervisor, the sense of duty, to improve operations. Each employee is stimulated by the Incentive Awards Program. The supervisors get an additional inducement: the Management Improvement Program.

The purposes of the Incentive Awards Program are: 1) to solicit suggestions from all employees to improve operations and to support moral, and 2) to establish honorary and monetary awards for the recognition of special employee achievements. Since recognition and reward are involved, the program provides a powerful incentive for employee participation. Furthermore, suggestions have often planted the seed for more formal investigative activity.

The main purpose of the Management Improvement Program is to instill, in supervisors at every level, recognition of a very basic precept of management. I.e., those who are responsible for various operations are likewise responsible for continual evaluation and improvement in the methods for performing these operations.

Relationship with Other Organizations

The Army Map Service is convinced that not knowing what is going on in the great outside world would be an unpardonable crime. Ignorance, here, as is usually the case, would be a voluntary affliction. Therefore, we believe in the widest possible liaison with mapping, research and development organizations, and industry.

Our closest liaison, of course, is with the Corps of Engineers Geodesy, Intelligence and Mapping Research and Development Agency (GIMRADA); this organization is looking into the future—at times, far beyond our vision. We closely support each other's complementary activities. And—should an AMS investigation result in a development contract, the matter is turned over to GIMRADA. Also, GIMRADA maintains official liaison for AMS with the R&D organizations of the Air Force.

AMS' next closest liaison is with our sister military mapping agencies. E.g., both AMS and the Aeronautical Charting and Information Center have exchanged permanent liaison officers. And—speaking for AMS, we have certainly profited from our associations with the U. S. Coast and Geodetic Survey, U. S. Navy Oceanographic Office, and the U. S. Geological Survey.

The AMS relationship with foreign organizations has been equally fruitful. The British Ordnance Survey first awakened our interest in analytical aerial triangulation. We are indebted to the National Research Council of Canada for work on APR and the Azimuth Camera technique. Also, our versatile Canadian neighbors (Hunting Surveys, Ltd.) have given us the Stereomat.

Finally, we come to the technical societies. AMS is fully aware of their importance in providing means for the exchange of ideas and in supplying committees to pursue vital work of common interest. We are proud of the individual support given to the American Society of Photogrammetry by our employees. And—we have accepted every request of the International Society for Photogrammetry (ISP) for participation. Presently, three of our investigations are in support of the ISP.

Present Program and Recent Findings

The present AMS photogrammetric improvement program is all user investigation and evaluation. A number of the more active of the current projects, and some preliminary findings, are as follows:

Investigation of the 120° Superwide Angle System. The purpose is to determine the accuracy and economy of the system in the AMS Mapping program. The investigation involves the use of 10,000-, 20,000-, 30,000-, 34,000- and 37,000-foot altitude RC-9 photography in a variety of equipment, in both aerial triangulation and stereocompilation phases of the work. The equipment used to date, has involved the: Wild Type-A U-3 Printer with compensating plate, Zeiss/Jena Multiplex, Wild Autograph A-9 and Aviograph B-9, the Zeiss/Aerotopograph Supragraph and the Kern Plotter. We also plan to evaluate the system by means of the Bausch and Lomb Balplex Superwide Angle Plotter, the Wild Aviograph B-8, and analytical aerial triangulation. Also, in collaboration with GIMRADA, we eventually expect delivery of lenses for the superwide angle version of our M-2 Plotter.

TABLE 1

SINGLE TERRAIN MODEL—VERTICAL RESULTS—RC-9 PHOTOGRAPHY

Instrument	*Altitude (feet)*	*Number of Operators*	*Orientations per Operator*	*Points Withheld*	*Altitude* *Av. RMSE*
Autograph A-9	20,000	3	1	33	6,873
	30,000	2	1	90	8,467
Aviograph B-9	20,000	3	1	39	6,100
	37,000	3	1	60	5,900
Multiplex[1]	10,000	1	3	28	5,263
	20,000	1	3	35	4,444
	34,000	1	3	33	4,473

[1] Coulthart, D. E. "Ultrawide Angle Multiplex Test Results," ACSM-ASP Meeting, Washington, D. C., March 1961.

The only results on this subject, that we are in a position to speak about publicly at this time, are those of the single model, Z-coordinate. These concern three instruments and are summarized in Table 1.

OPERATIONAL TEST OF APR-HIRAN

The objectives are: 1) to determine the horizontal and vertical accuracies which may be obtained from simultaneously recorded airborne data procured with HIRAN and the MK-6 APR equipment in the RC-130A aircraft at 20,000 and 35,000 feet above sea level, over predominantly level terrain where the flight lines are relatively short, 2) to train key personnel and test new methods of application of the APR-HIRAN data, and 3) to determine the density and distribution of ground control required to supplement the recorded airborne data to achieve the results desired for operational topographic mapping.

This project is in the final report writing stage. A summary of the results is as follows: 1) Ninety percent of all horizontal positions derived from the HIRAN data are accurate to within 36 feet. 2) Ninety percent of all elevations derived from the Mark VI APR data are accurate to within 13 feet. It should be pointed out that this accuracy was obtained with flights which were less than 35 miles long, and that some difficulties were experienced operating the APR equipment over mountainous terrain.

EVALUATION OF A GENERAL ANALYICAL SOLUTION TO THE PROBLEM OF PHOTOGRAMMETRY (ANALYTICAL AERIAL TRIANGULATION)

This project is also a collaborative venture with GIMRADA. It involves: 1) programming the method of Dr. Hellmut Schmid for the Honeywell H-800 computer, 2) procurement and calibration of a Zeiss/Aerotopograph PSK Stereocomparator, 3) absolute evaluation of the Schmid method in wide angle, superwide angle and, if possible, convergent modes, and 4) comparison of the method with current AMS aerial triangulation production techniques to determine the relative accuracy and economy of the two systems.

EVALUATION OF THE STEREOMAT III (AUTOMATIC CONTOUR PLOTTER).

This project is an evaluation of the 2-tube Stereomat, as installed on a Nistri Photocartograph Model IV Stereoplotter by Hunting Surveys Ltd., Toronto, Canada. It is a continuation of GIMRADA's work on the Stereomat. Also, it is in support of the International Society for Photogrammetry's Commission IV, "Working Group on Small Scale Mapping."

The program involves an analysis of: relative orientation, absolute orientation, automatic contouring, and automatic profiling. A minimum of seven stereo models, selected to provide various types of terrain, vegetation, and cultural detail, are being used. Duplicate tests are being conducted on the M-2 Stereoplotter for comparative purposes.

The indications, to date, based on the preliminary evaluation of five test models of five different areas, are as follows: 1) the repeatability of relative orientation of the Stereomat-III, as indicated by successive orientation tests, is superior to that of manual relative orientation on the M-2

Stereoplotter; 2) the speed of contouring of the Stereomat is superior to that of an operator on the M-2 by factors of from 2 to 3, depending upon the model characteristics, i.e., the extent of areas of poor image correlation caused by extremely steep slopes (30° or more), flat areas (less than 3° slope), or lack of detail; and 3) there is a significant deterioration of contour accuracy in drainage turnbacks, and on sharp ridge lines. It is expected that these deficiencies will be largely overcome in Hunting's Stereomat IV, as incorporated in the Wild Aviograph B-8. Delivery of the latter instrument to AMS is expected shortly.

STEREO MODEL DEFORMATION

This project is being conducted in support of the International Society for Photogrammetry's Commission II, "Working Group on Fundamental Problems." It is in recognition of the contention of the experts, notably, Professor Hallert, that much work remains to be done to determine answers for questions which concern the very foundations of photogrammetry. It is upon the answers that the whole structure rests. Therefore, any new, or better understood, information should produce a chain reaction of improvement possibilities.

The objectives are to study four areas of stereo model deformation: 1) in observation, 2) in instrumental orientation procedures, 3) in the affine model, and 4) the effect of relief on model accuracy.

ISP COMMISSION IV EXPERIMENTAL RESEARCH TEST

This project was set up to support the International Society for Photogrammetry's Commission IV, "Working Group on Cadastral and Large Scale Mapping." The pertinent resolution adopted at the ISP 1960 Congress in London expresses the purpose of this work as follows, " . . . to determine the instrumental and subjective errors pertaining to the various operational phases as well as the relevant law of error propagation as applied to photogrammetric surveys at various scales."

The plan of test was drawn up by the ISP and involves the use of Zeiss RMK 15/23 photography taken at an altitude of 4,000 feet over the Reichenbach, West Germany test area. The ISP is supplying everything but plotting instruments and operators. Each of two operators oriented the test stereo model containing 50 panelled points on both a Stereoplanigraph C-8 and an Autograph A-9. Each operator then made two independent sets of readings of each of these two orientations. In all cases, three consecutive pointings were made. The coordinates of 45 of the 50 points were withheld.

INVESTIGATION OF THE AZIMUTH CAMERA TECHNIQUE IN PHOTOGRAMMETRIC BRIDGING

Tests performed, first at the National Research Council (NRC) of Canada, and, later at the Army Map Service, have shown that Airborne Profile Recorder (APR) data can be used not only for vertical control of photogrammetric strips, but also, to a limited extent, for horizontal control. These investigations have also shown that the only element lacking from what would otherwise be complete airborne control over a photogrammetric strip, in a single package of APR data, is a method of determining the azimuth of the strip.

One method of overcoming this deficiency was proposed by Mr. P. E. Palmer[2] of the Topographical Survey of Canada. This proposal involved the use of an auxiliary aerial camera, fixed in attitude so as to photograph the horizon simultaneously with conventional vertical exposures. As a result of this suggestion, NRC developed and tested the "continuous-line" method of azimuth control, which, while successful, was found difficult to apply. Subsequently, NRC developed the "line-segment" technique, a more practical, yet equally effective, method of controlling the bend of photogrammetric strips.

The objectives of the AMS investigation are: 1) to determine the capability of the azimuth camera "line-segment" technique to compensate for the "y," or azimuth, deflections normally encountered in photogrammetric bridging between control with long lines of aerial photography, 2) to determine the applicability of this technique to AMS map production methods, 3) if found to be of sufficient benefit, to train key personnel in the application of the technique, and 4) to determine the density and distribution of ground control, and the number of line segments, required in order to achieve optimum compensation for the bend of photogrammetric bridges.

Azimuth camera photography, and vertical photography, flown at an altitude of 30,000

[2] Palmer, P. E., "Application of Bi-Camera Photographs to Bridging," PHOTOGRAMMETRIC ENGINEERING, Vol. XX, No. 1, March 1954.

feet over California, Nevada, and Arizona in 1958 and covering approximately 515 linear miles of terrain, will be used in this test. The control is spaced with an average interval of 22 miles along the flight line.

Each strip of vertical photography will be bridged on a first-order aerial triangulation instrument, using a method of bridging specifically designed for this test. Adjustments of the photogrammetric data will be made to ground control, considering variations in the following parameters: strip lengths and numbers of oblique photos, line-segment points, and ground control points.

Future Program

As with our present improvement program, our anticipated work will be all user investigation and evaluation. Giving credit were credit is due, the heart of this program is in direct support of GIMRADA's far-flung R&D efforts. In this category, our plans involve user investigation and evaluation of such items as: 1) the Zeiss Supragraph, 2) SHIRAN, 3) Automatic Map Compilation System, 4) Digital Automatic Map Compilation System, and 5) the Dual Aircraft System.

SUPRAGRAPH

This analogue computer/plotter was designed and built by Zeiss/Aerotopograph. It can accommodate wide, or superwide, angle photography and can be used for aerial triangulation, compilation, and also as a stereocomparator. The instrument was described in detail by Mr. H. Traeger, Zeiss engineer.[3]

The Supragraph is a prototype instrument and, understandably, is still in the shakedown and debugging stage. Preliminary indications are, however, that Z-coordinate grid accuracies of 1/50,000 of the projection distance can be attained.

SHIRAN

Whereas HIRAN operates in the 230–300 megacycle range, and employs one airborne set and two ground sets, SHIRAN, on the other hand, operates in the 3,000 megacycle band, and one airborne set is capable of interrogating as many as four ground sets simultaneously. The data reduction time for SHIRAN will be reduced over that required for HIRAN, since the SHIRAN measurements will be recorded on magnetic tape, and fed directly into an electronic computer.

The better geometry of the SHIRAN configuration should provide a corresponding improvement in accuracy. Existing accuracy predictions are conflicting, which conflict should be resolved by extensive, rigorous testing.

AUTOMATIC MAP COMPILATION AND DIGITAL AUTOMATIC MAP COMPILATION SYSTEMS

These plunges into automation by GIMRADA are meant to radically speed the mapping process. Both will produce orthophotomaps, contour data and UTM grid marks. The systems have been described in detail by various GIMRADA and contractor papers.

It is anticipated that, upon completion of GIMRADA's engineering tests, these systems will be turned over to AMS for comprehensive user's evaluations. In the latter phase, of course, the systems will be rigorously compared with conventional methods and other new systems such as the stereomated, orthophotographic Aviograph B-8.

DUAL AIRCRAFT SYSTEM

This system involves the determination of the distance between two photographic airplanes flying parallel flight lines. The feasibility of the technique has been determined by preliminary work of GIMRADA involving real data. GIMRADA has recently suggested that AMS conduct a more comprehensive, operational test of the system.

Conclusion

I hope this presentation has served to give a clearer picture of the AMS position in the photogrammetric improvement field. We are neither an uncouth, overalled map factory, as some may be occasionally tempted to think nor are we a leading R&D organization, as some contractors tend to flatter us at opportune times. If, however, in the process of being ever on the alert for improvement, we take on an image that resembles what some would consider an R&D outfit, well—we apologize to all bona fide R&D organizations.

[3] Traeger, H., "The Supragraph—A New Maximum Precision Plotter with Mechanical Analog Computers," ACSM-ASP Meeting, Washington, D. C., March 1962.