SYMPOSIUM OF IDEAS RELATIVE TO EDUCATION IN PHOTOGRAMMETRY

Compiled by A. O. Quinn, Assistant Professor of Photogrammetry, Syracuse University and G. C. Mares, Photogrammetric Engineer, U. S. Naval Photo Interpretation Center

FOREWORD

THE Publications Committee did not get started on its program of dedicating each issue of Photogrammetric Engineering to a particular phase of photogrammetry until late in the year. Therefore, it was only through the hard work of Professor Quinn and Mr. Mares that the accumulation of ideas contained in this symposium are available for this issue. The Society is very fortunate to have members who are willing to devote so much of their spare time to committee work. On behalf of the Society, I take this opportunity to express our thanks to Professor Quinn and Mr. Mares for a most difficult job well done. Also, we wish to thank each individual who has contributed to the symposium. The names of the various contributors are appropriately shown in the following pages.

It is the wish of the Publications Committee that a program will be established whereby Photogrammetric Engineering may publish, from time to time, discussions on photogrammetric education. In this manner it is hoped that many schools will be aided in the establishment and inclusion of adequate photogrammetric training in their educational programs.

P. G. McCurdy,
Chairman, Publications Committee

INTRODUCTION

The purpose of this issue of PHOTOGRAMMETRIC ENGINEERING is to present to the members of the Society, a symposium of ideas on the teaching of photogrammetry in the various colleges and universities.

The Publication Committee has solicited comments from two groups: one, those currently teaching photogrammetry and two, those using photogrammetry to solve surveying and mapping problems. In addition to requesting general comments, the following specific questions were asked of the latter group:

1. What is your recommendation as to the amount and content of courses in photogrammetry that should be given in colleges to better fit graduates for photogrammetric work in your organization?
2. In your opinion, should the colleges stress the fundamental theories of photogrammetry, leaving the practical applications to the organizations employing the students after their graduation, or should the college attempt to do both?
3. Would your prefer to employ a college trained man having specific photogrammetric work, say in the operation of the multiplex or other stereophotogrammetric instruments, or one with considerable general knowledge of photogrammetry and allied surveying subjects?

The college group was asked to outline their present and future plans for courses in photogrammetry together with any discussion of required equipment and photographic materials.

The Committee has received excellent response, and the articles and comments which follow should be of inestimable aid in the formulation of future plans for furthering the science of photogrammetry. The Committee wishes to express it's sincere appreciation to those who have so generously contributed material to give the members of the Society the benefit of their experiences in photogrammetry.

Many replies have been received from colleges who wish to start courses in photogrammetry and do not have an idea of where or how materials and equipment may be obtained. For their information it may be stated that surplus military equipment may be purchased from the War Assets Administration; aerial photographs taken for the various federal agencies are available (the Society, the U. S. G. S., and others publish maps from time to time showing the status of aerial photography throughout the nation), and numerous commercial firms (see advertisements in this issue) have photogrammetric equipment and supplies for sale.

To achieve the most effective sequence of presentation, the various articles and comments have been grouped in the following manner: I. Commercial organizations and governmental agencies; II. Educational institutions; III. Professor Church's, "A Discussion of Some Basic Principles of Photogrammetry."

I. Commercial and Governmental Agencies

O. M. Miller, American Geographical Society

The photogrammetrical worker in the sub-professional group can be usefully employed with no or very little theoretical training. These remarks, therefore, apply only to the training of professional photogrammetrists.

Professional photogrammetrists should have considerable knowledge of photogrammetry in general and related subjects rather than merely experience in working with photogrammetric techniques and in operating photogrammetric instruments.

Colleges giving courses in photogrammetry should, therefore, in my opinion stress the fundamental theories of photogrammetry but should also, if equipment and time is available, introduce exercise work of a practical nature covering a wide variety of techniques.

The question naturally arises as to what background of prior training is necessary in order that the student can fully appreciate the basic theories of photogrammetry and their influence in practical applications.

I have not had sufficient experience in teaching photogrammetry to be able to give an opinion as to the time necessary to fit graduates for professional photogrammetric work. As to content of courses and previous background of training the following would seem to me to be desirable.

Preliminary Training

Mathematics

- Elementary analytical geometry of space.
- Plane and spherical trigonometry.
- Elements of differential calculus.
- Elementary theory of equations.
- Elementary theory of errors and their adjustment including the method of least squares.
- In addition it would be of immense value to the student to acquire a knowledge of matrix algebra and integral calculus.

Physics and Chemistry

- A first course in physics emphasizing physical and applied optics.
- An elementary course in chemistry.

A first course in the theory of photography.
An introductory course in electronics.

Mechanics

A general course in mechanical design emphasizing the broad principles of good design and the meaning of technical terms rather than a course to enable the student to become proficient in mechanical drawing, though the latter would also be desirable.

Geodesy and Cartography

A specially prepared course in geodesy, map projections, plane surveying, map compilation and map printing emphasizing the nature of the problems encountered. In this course it would also be desirable to give the student some historical background and also acquaint him with the activities of the various surveying and mapping organizations both government and private.

Miscellaneous

A first course in business administration emphasizing the preparation of reports.
An elementary course in physical geography and the interpretation of aerial photographs.

Instruction in Photogrammetry

A full course in photogrammetry might well include the following subjects in the order as given. Suitable exercises should be given concurrently with each subject and at the end of each course the students as a group should be given a complete mapping project to perform.

1. The place of photogrammetry in surveying, mapping and allied subjects. This should include a general historical review.
2. The camera as a precision instrument. This would include the design, construction and calibration of survey cameras and the characteristics of photographic materials.
3. The perspective geometry of a single photograph.
4. The perspective relationship between two or more photographs.
5. The geometrical relationship of a space model to the terrain.
6. Stereoscopy, its theory and fundamental application in photogrammetry.
7. Photography in the field.
8. Ground control, its classification and utilization in photogrammetric techniques. Radar systems for controlling position.
9. Assuming the exterior orientations of photographs to be known, graphical and computational methods of fixing the positions of points imaged in the photographs and non-instrumental methods of plotting detail. This would also include the compilation of mosaics, and the auxiliary use of aerial photographs in ground surveys.
10. Non-instrumental methods of determining exterior orientation.
11. Non-instrumental radial line control techniques.
12. The instrumental approach, its history and development.
13. Monocular measuring instruments.
14. Binocular measuring and plotting equipment. Here emphasis should be on the fundamental differences in the mechanical and optical characteristics of the various instruments in use and in their operation.
15. Instrumental methods of obtaining absolute and relative exterior orientation.
16. The theory and practice of photo-rectification.
17. Problems in the extension of control by aerial triangulation, including the accumulation and adjustment of errors.
18. A general review of photogrammetrical mapping systems in use.

Leon T. Eliel, Vice President Fairchild Aerial Surveys, Inc.

It is my belief that at the present time educational institutions teaching courses in photogrammetry put too much emphasis on the science of photogrammetry and not enough emphasis on the art of photogrammetry. Students are given a great deal of theoretical mathematical background for solutions of tilts and various other complicated mathematical processes, which are practically never employed by us in practice. There probably are not as many as twenty people in the United States who spend very much time on the theories of photogrammetry, while there are hundreds of people engaged in various phases of practicing the art of photogrammetry. These hundreds of people do all sorts of things, from putting in field control to computing radial control plots, laying out radial control plots, computing the prints for mosaics, laying out grids and projections, drafting, editing, and similar things. All of the computations which are ever involved in the practice of photogrammetry are certainly no more complicated than plane trigonometry. There is no occasion to go into heavy mathematics for the average person employed in a photogrammetric institution. My answer, therefore, to the first question, is that colleges should put more emphasis in the practical training of the art of photogrammetry.

Our ideal employee is one who has a general knowledge of civil engineering, a considerable knowledge of surveying, and at least a fair fundamental knowledge of simple photogrammetry. Training in the operation of the multiplex is good general background, although in our organization of about 250 people there are only actually about eight who operate stereoscopic plotting machines.

We would like to employ people in our organization who have an engineering training so that they are thorough and careful in their thinking, fast and accurate in their execution, and with enough general comprehension of the geometry of the picture and the background of photogrammetry to be able to pick up the particular phases of the work to which they may be assigned, quickly.

Harry Tubis, President, Harry Tubis, Inc.,

The desirable amount of college training in photogrammetry can be encompassed in probably two years of work. It is my understanding that this is the plan prevailing at Syracuse University, the specialized study in photogrammetry being offered to undergraduate students in the junior and senior years. I have had the opportunity to employ and observe the work of graduates of Syracuse and other universities who have taken the courses and believe this length of training satisfactory. Up to this time, I see no field of practical application of photogrammetry which could effectively utilize the amount of education provided in a course of four or five years' duration. Of course, the teaching profession would be an exception to this. Regarding the content of the courses, I think this is best answered in my reply to your next question.

It is my firm conviction that a full time course in photogrammetry should both teach the fundamental theories and give training in the practical aspects of photogrammetry. I have had occasion to employ students who had "majored" in the theoretical aspects and in the practical applications of photogrammetry. As employees in the commercial field, I would prefer men who were educated in both phases and, preferably, with the weight on the practical training.

Over a period of about fifteen years, as an employer, I have seen the necessity for much practical training on the job, in setting up governmental and commercial mapping organizations.

Assuming a two year course, I would suggest the first year be devoted to the theoretical considerations of photogrammetry; the second year to concentration practical training in one or more branches of photogrammetric surveying or map making. Also, I cannot stress too strongly that the photogrammetry major student should have had thorough courses in higher surveying, topographic mapping, and theory and practice of map projections. If the usual college engineering course in its first year does not provide sufficient opportunity for education in these subjects, they could be provided as part of the practical training in the final year. The following are suggested branches of photogrammetric surveying and mapping in which practical training could be offered:

1. Planning and execution of control surveys.
2. Planning and estimating photographic missions.
3. Economics and practical elements in the operation of a photographic laboratory.
4. Operation of Multiplex equipment.
5. Procedures and techniques of controlled mosaic compilation.

In addition to the above I have a further suggestion to make and that concerns the possibility of arranging short periods of employment in industry for students of photogrammetry, similar to the "cooperative" plan of engineering education. I realize that this may make it necessary to lengthen the course of training to three or even four years, but this is a subject which might warrant further consideration.

Wm. H. Meyer, Jr., Lockwood, Kessler and Bartlett, Inc.

To adequately answer the committee's questionnaire would require a thesis of considerable length. It is my opinion that the aerial photographic industry has overlooked for many years the advantage of encouraging engineering institutions to include courses on photogrammetry and its application toward the solution of many phases of engineering. If such instruction had been available for the last twenty years many thousands of engineers today would have a far better working knowledge of photogrammetry.

A few institutions should make available a complete course in photogrammetry and establish a degree of Photogrammetric Engineering. There is a limited field for thoroughly trained men in this field to become Chief Engineers of this work. A few large organizations will have departments or divisions solely devoted to photogrammetry and will need a man to control and plan the work. Most of the workers, however, are trained or experienced technicians who are necessarily limited to particular phases of operation to facilitate production, and their remuneration is not sufficiently high to warrant the time necessary for a thorough engineering education in photogrammetry. One Chief Engineer can supervise and train a large number of production workers. Training of too many photogrammetric engineers would be unwise as there are but a limited number of opportunities with the government agencies, commercial companies, or educational institutions.

The emphasis in planning courses in photogrammetry should be in the use of the material as an aid to some group, such as geologists, foresters, civil engineers, pipeline engineers, highway engineers, railroad location engineers, transmission line engineers, and city planning engineers. Design the courses as to subject matter so that students of such fields will know the advantages and limitations of photogrammetry. I would recommend that several courses in photogrammetry be required for any engineering degree in conjunction with a more complete course in surveying and map making; the general goal to be to prepare a student to use photogrammetric work. There will be many more opportunities for those who know how to use the material in relation to other phases of en-

gineering than for those who produce photogrammetric work.
Courses to include:

A. Types of photogrammetric equipment and cameras.
   1. Operation.
   2. Relative costs.
   3. Advantages and limitations.
B. Methods of control.
   1. Ground surveying for horizontal and vertical control in photogrammetric work.
   2. Radial line control as well as a study of the relative accuracy based on horizontal field control distribution.
C. Photo interpretation.
D. Photographic laboratory products—their advantages and disadvantages.
   1. Contact prints.
   2. Enlargements from original negatives.
   3. Ratio prints.
   4. Copying negatives and prints of mosaics.
E. Instruction and laboratory work, if possible, to prepare:—
   1. Photo index maps.
   2. Controlled mosaics.
F. The commercial uses of aerial photographic products for petroleum geology, forestry, highway location, telephone line location, city planning, topographic mapping, and tax maps. A thorough explanation as to the most suitable products, scale, types of maps, and the procedure to secure a series of economical yet satisfactory groups of material, and whether these products should include contacts, enlargements, controlled mosaic, or topographic map and if so in what scale and what contour interval.
G. Thorough study of estimating procedure so that it would be possible to estimate the labor and material cost on a given project; data as to flying information, spacing of flight lines, computing the number of exposures, number of copy sections necessary, and such relative material.

It is my thought that the tendency should be toward the education of users rather than producers of photogrammetric work, as in the automotive field a very small number of automotive engineers produce the automobiles used by thousands so that we should be more interested in training the drivers of the automobiles rather than the producers.

James J. Deeg, Chief, Mapping and Charting Branch, Wright Field, Dayton, Ohio

My observations concerning the needs and problems of industry and educational institutions in connection with mapping and charting could fill a couple of volumes. Many individuals with a few years of experience in this field of endeavor are beginning to recognize the shortcomings of most of our educational institutions, but do no more than "gripe" about the situation. A few of the "old timers" are trying to rectify this deplorable condition and have been successful in establishing some phase of photogrammetric instruction in our leading universities. Any aerial survey contractor will elaborate at great length on the short-comings and problems related to industry. Most of the successful companies are in the market for qualified personnel and would pay well for a stable photographic airplane or a reliable verticality indication device. It is sincerely hoped that these few words will be of material help to various institutions who now recognize the necessity of offering courses in photogrammetry.

I shall attempt to outline the amount and content of subjects that should be included in a course of instruction. Studies along these lines would better fit graduates for work in any organization interested in mapping and charting. In general, our educational institutions should follow the engineer currciulum pattern already established, but with certain modifications. Fundamental theories should be stressed; but they should be supplemented with practical applications on a laboratory scale. Specialization may follow when it has been determined that the individual has an interest or is in a position to contribute something noteworthy. He should *not* be permitted to study or prepare a thesis on some absurd or equally unprofitable subject such as "The Love Life of Fruit Flies in the 10th Century B. C."

Our colleges should train photogrammetric specialists; but any individual should not be eligible for the specialized training until he has a firm grasp of the overall basic fundamentals of mapping and charting.

While the American Society of Photogrammetry defines photogrammetry as "The science or art of obtaining reliable measurements by means of photography," the definition of the word "photogrammetry" is unknown or rather obscure in the minds of many people in responsible positions related to mapping and charting. Oftentimes, these same people do not make the effort to understand what is implied by photogrammetry. Others resent the adoption of anything that may detract from older established professions. Even within the American Society of Photogrammetry membership there is a great difference of opinion concerning the definition of the word photogrammetry.

Since I have not consulted Gallup or any other less highly advertized group on "photogrammetry definition understanding" percentages, I must trust my own observations and experience which dates back of 1929. I find two main groups of "believers." Group One is of the opinion that a photogrammetric engineer is concerned with one phase of mapping and charting i.e. the obtaining of reliable measurements by means of photography. This consists primarily of mathematical computations related to the tilt analysis of an aerial photograph coupled with a limited understanding of base projections and multiplex operations, etc. These "believers" would like to be placed in the "rare bird" category. Some organizations can afford personnel with such limited or specialized capabilities. Group Two consists of a more versatile and valuable type of personnel with a good understanding of all phases of mapping and charting. Their knowledge runs the gamut from planning a photographic mission to the distribution of a completed map or chart. Personnel with these qualifications have proven to be an asset to any mapping or charting organization. It is not wished to imply that a "jack-of-all-trades" is desirable. A little bit of knowledge is still a dangerous thing. A well rounded course of instruction is mandatory. This holds true for any form of education. Specialization will come later on with little guidance. In due time, I believe, courses of instruction in Mapping and Charting will be on a par with courses given to Chemical, Electrical, Mechanical and Civil Engineers. Any course established at this time will be modified as circumstances demand. The main requirement is that *more* colleges of recognized standing offer courses in photogrammetry.

To tell what desirable characteristics a qualified person must have in order to be an asset to a Mapping and Charting organization compels me to relate another definition. At one time, the examination for flying cadets was considered "very rugged." It was so "rugged," in fact, that the definition of a pilot written by some frustrated flying cadet on the wall of a padded cell during a mental storm read as follows: "A pilot must possess the innate faculty of selective and instinctive discrimination of the stimuli of the sensor motor apparatus to adjust harmoniously metabolic changes in physiological and psychological equilibrium in such manner as to comprehend and assimilate instruction in the attributes essential to perform the intricate and complex operations which constitute the details of pilotage."

To the same extent, the characteristics of a photogrammetric engineer can be distorted or exaggerated by some well meaning people and result in a similar definition. Oftentimes, I am of the opinion that all photogrammetrists belong in a padded cell. I have never seen any one group who can become so completely absorbed with a particular subject.

I am interested in personnel that can be utilized in photogrammetric research. Due to many unpredictable factors, it is mandatory that personnel be capable of serving as project engineers on many phases of mapping and charting research. At times, they must be inventors, diplomats, salesmen, confessors of human emotions and report writers. Much of the experience gained in these fields of endeavor must be obtained from the old college of "hard knocks." Some years hence, these important subjects may be included in the curriculum of an institution of higher learning offering a course in photogrammetry.

A man and/or woman with a majority of all of the following qualifications will never have to worry concerning steady employment. Any agency of the Government or a commercial organization would consider this person an asset to their staff.

1. Must know how to plan a mission and pilot an airplane on a mapping or charting flight. (If they cannot pilot the plane, it is most helpful if it is at least understood that propellers are not used in conjunction with a motor in order to keep it cool.)

2. It is preferred that the person have a thorough knowledge of aerial photography, aerial cameras and accessories, processing of film and making of contact prints, ratioed and rectified enlargements, laying of mosaics and operation of copy cameras.

3. He should be a graduate civil engineer with some field experience. This field experience should include the use of aerial photographs and the determination of geodetic positions from astronomical observations.

4. He should be very familiar with various map projections and understand their respective limitations.

5. He should be able to operate or at least understand the working fundamentals of instruments intended for the transfer of data from an aerial photograph to a base projection. In this category should be listed such items as sketchmasters, plotters, templets, stereoscopes, height finders, multiplex equipment, stereo-comparators, stereoplanigraphs, etc.

6. A good knowledge of terrain model building is very essential. This should include practical experience in the use of latex compounds, plastic, metal, papier-mâché and other terrain model building techniques.

7. He should understand the fundamentals and have some experience in graphic arts, especially those phases connected with map or chart reproduction. In this category would be such items as plate producing copy cameras, sensitized plates, photolithography, offset and letter press operation, grainers, whirlers and graphic arts chemicals. Many times the map or chart compilation procedures may be altered in such fashion as to expedite the work of graphic arts personnel with a general saving in time and appearance of the finished product.

8. With the advent of electronics and radio into the field of mapping and charting, an individual is lost if he does not understand the basic fundamentals of these important subjects. His schooling and experience in electronics and radio need not qualify him for a doctor's degree, but may very well enable him to initiate additional study if he finds it interesting and profitable.

9. In addition, the individual must have a "generous dose" of mathematics (including integral calculus), business English and business law, specification and report writing, at least one foreign language, public speaking, shorthand and typing, *and a course in how to get along with other people.*

Very seldom do you find one person with all of the above qualifications. Our aim should be in the direction which will yield the type of well rounded education required in the production of maps and charts. I see no reason why some of our larger, wide-awake educational institutions cannot establish a course of instruction which will warrant the award of a degree in photogrammetry after four years of study. In time, such additions may be made to the course of study which will lead to a master's or a doctor's degree. Photogrammetry has outgrown the period of adolescence. It requires a person with a good knowledge of mathematics, mechanics, aerodynamics, physics, chemistry, electronics, optics, graphic arts, business administration and personnel psychology.

Eldon D. Sewell, Chief, Aerial Photographic Branch, Engineer Research and Development Laboratories, Wright Field, Dayton, Ohio

Since the Committee questions are so closely related no attempt will be made to answer each one separately. Instead, general comments on the suggested topics will be made. It should be understood that my experience in employing photogrammetrists is very limited and most of my conclusions are necessarily based on theoretical considerations rather than actual. However, during my six years in the Army I had the opportunity to train and observe the training of a large number of men in various phases of photogrammetry. Since only a fractional percentage of them had had any formal photogrammetric schooling it is difficult to compare them with college graduates who have majored, at least to some extent, in photogrammetry.

I believe that a college offering photogrammetric training should divide the work in such a way that the student is given an adequate background in the fundamental theories of photogrammetry and also some practical work with modern photogrammetric equipment. In order to do this it seems that a minimum of two years' work with a three or four hour course for each of the four semesters would be necessary. If a college plans to offer only a limited course in photogrammetry (say one semester), I think the entire time should be devoted to the study of theory.

The first semester would be required to introduce the student to the general science of photogrammetry. A few hours should be spent on teaching the principal elements of a modern mapping camera, the precision required and the method of calibrating. The student should be taught how errors due to film shrinkage, lens distortion, and errors in the focal length of the camera and in the position of the principal point cause compilation errors. He should be taught how to plan a flight mission so that proper side lap and overlap are assured and also how to lay an uncontrolled mosaic. He should be required to learn definitions of various words that pertain to photogrammetry, such as principal plane, nadir point, principal point, isocenter, tilt, swing, parallax, air base, etc. Only by learning proper nomenclature will a student be able to read easily or discuss readily subjects on photogrammetry.

As the student advances he should be given instruction on analytical and graphical solutions of vertical photographs and the theory of radial line plots. Practical problems on these subjects should be worked by the student.

Only after the student has a working knowledge of the subjects mentioned above should he be given instructions in the solution of tilted photographs. After preliminary instructions on tilted photographs, analytical and graphical methods of determining the exposure station and the elements of exterior orientation should be given. Practical problems in space resection and intersection should be solved. Instruction on use of low oblique photographs, high oblique photographs (trimetrogon) and on rectification could follow.

I believe that work with stereoscopic plotting instruments and with other photogrammetric equipment should start at this time. Exercises with the stereocomparagraph, the contour finder, slotted templates, mechanical templates, sketchmasters, rectoblique plotters, Multiplex, comparator, etc. should be given if equipment is available. Of course, some of the equipment just listed might well be introduced and used prior to this stage of instruction.

I am of the opinion that most of the time spent in the class room should be used in teaching the fundamental theories of photogrammetry. Only enough time should be spent on the equipment to familiarize the student with what the particular instrument is capable of doing and a general knowledge of how it is operated. I believe that over a reasonable period of time a person having a background of theoretical photogrammetry would be of more value to an organization than a person skilled in the operation of a single photogrammetric instrument or procedure.

Courses in geodetic surveying, optics, map projections, meteorology and projective geometry would be of great value to the student studying to be a photogrammetrist. Since electronic equipment (shoran, loran, radio altimeters, Raydist, etc.) is being used more and more for obtaining ground control for aerial mapping a general course in electronics would not be out of order. If, after a semester or two, the student has decided definitely the branch of photogrammetry he wishes to follow he can perhaps choose his "extra" subjects more wisely.

If the time and equipment are available it would be well for the student to participate in an aerial mapping flight, to learn to process film, make prints and diapositives in the darkroom, and to visit commercial mapping firms or Government agencies to observe how maps, charts, and mosaics are made.

Of course only a few colleges today have the necessary equipment for offering a course covering the subjects mentioned above. Since the ultimate objective of the photogrammetrist is to provide precise measurements of objects or distances on the ground from measurements on aerial photographs, courses in photogrammetry should be planned to properly equip the graduates for this work.

G. S. Andrews, Air Survey Engineer, Department of Lands and Forests, British Columbia

I believe that a general civil engineering course, with opportunity to "major" in photogrammetry would be the best compromise with time available during undergraduate years. The graduate should have a good general foundation in engineering plus a grounding in photogrammetry sufficient to enable him to follow up more specialized aspects afterwards.

Practical work should accompany theory—both in laboratory and field, just as in orthodox survey courses, Also, a condition for qualifying each year should be employment in the field during summer vacation—on some phase of photogrammetric application—including if possible one season flying for air survey. We prefer general knowledge plus some "exposure" to the standard plotting techniques.

One or more season's experience on some kind of field survey during the undergraduate period is a fundamental advantage in the appreciation and effective use of photogrammetry later.

I think most organizations have their own individual practique and slant on the actual application of photogrammetry—and are willing and probably prefer to adapt new personnel to it, especially if the person has a good general knowledge to offer.

In my organization I try to get promising individuals in the air for at least one season's air survey operations, and vice versa, to get the flying crew through the plotting and other indoor phases during the off season.

*John Carroll, Topographical Survey, Department of Mines and Resources, Canada**

The pressing post-war demand for adequate maps of many parts of the Dominion of Canada has promoted a large expansion in the mapping functions of the Topographical Survey, Bureau of Geology and Topography, Department of Mines and Resources, Ottawa, and a concomitant increase in employment of personnel for photogrammetric work. These new persons have been drawn largely from the survey and air crew establishments of the Armed Forces, as the training they received in those units can be utilized in the photogrammetric work at present carried out by the Topographical Survey. The photogrammetric work they are presently engaged upon is generally routine, in the compilation of planimetric maps and, as their experience grows, they become skilled craftsmen upon various phases of it.

This situation is, however, not static. There is an ever-expanding popular demand for topographic maps of high accuracy. The employment of stereoplotting equipment and methods are envisioned, and this will create a requirement not only for skilled craftsmen, but also for a certain percentage of personnel who have had graduate training in photogrammetry and surveying of a standard to fit them, not only at keep abreast of new techniques being developed, that may have application to topographic mapping such as the electronic systems of Radar and Shoran, but also to undertake research and development into all phases of photogrammetry and allied subjects as they relate to the production of topographic maps.

It is felt that a university graduate, who would be of greatest use in a mapping organization in the field of photogrammetry, should have a sound and comprehensive knowledge of theoretic photogrammetry and surveying. A good mathematical background is considered most essential.

It is deemed important that universities should cultivate in the student the ability to use good English, to think clearly, logically and orderly, and to apply principles; should encourage accuracy, neatness and thoroughness in the jobs undertaken, and stress the importance of obtaining systematic independent checks thereon; should promote self-reliance and confidence in study of projects and search for solutions.

It is thought that the student should be taught the fundamental theories of photogrammetry, together with sufficient practical work to give a proper understanding of the theories. If the student is well grounded in the principles of photogrammetry, he can be readily assimilated into our mapping organization.

In normal course, the tendency would be to consider college trained men who have had general experience as being of most present value; however, occasions may arise when a college man, who has had considerable practical experience on specific photogrammetric instruments, e.g., multiplex, may, at the time, be deemed the most valuable.

William MacAdam, Forester, Great Northern Paper Company

The application of aerial photogrammetric techniques to the forestry and engineering problems of the forest industries has only recently begun to be ex-

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tensively explored and exploited. However, the rapid acceleration of the use of vertical aerial photography by both public and private agencies has already clearly demonstrated the advantages that are to be realized by such application.

The principal use to which aerial photography is today being put by the forest industries of the Northeast is in the compilation of planimetric forest type maps in timber survey work. The photogrammetric work involved is limited to the extention of horizontal control by means of radial plotting, interpretation of forest types and related detail based largely on the intimate knowledge of local conditions of experienced cruisers, and detail transfer with the Multiscope, Sketchmaster or vertical projector types of transfer devices. In the case of several recent contracts for aerial photography for large pulp and paper companies the deliveries have included mosaics and/or radial plot thus obviating the necessity for the first mentioned operation.

Limited application has recently been successfully made of techniques for estimating timber volumes directly from measurements made on vertical aerial photographs with a limited amount of checking on the ground to orient the interpreters and provide information on species composition and necessary deductions for rot and other defect. These estimates have been largely of the reconnaissance type but have clearly demonstrated the gains in accuracy and detail possible with attendant cost reductions using aerial photograph as contrasted with conventional cruising methods employing only ground measurements.

There remains, however, considerable work to be done in perfecting and simplifying existing aerial cruising techniques, and in developing volume tables for timber estimating from measurements on aerial photographs in several of the forest types of the Northeast, notably the commercially important spruce-fir types.

Limited use is also being made of vertical aerial photography for surveying, planning logging operations, locating woods camps, laying out logging jobs, locating roads, locating dams, delineating flowage areas, and other engineering work incidental to the operations of a large lumber or paper and pulp company.

The Bureau of Taxation, State of Maine is pioneering in the use of aerial photography for tax evaluation work on timberlands in that state. The United States Forest Service has done notable work on both the development and application of aerial techniques and equipment through its Northeastern Forest Experiment Station, as has the Harvard Forest, Harvard University.

From the industries' standpoint the present field of photogrammetry activity is one for the forester or forest engineer trained in basic photogrammetric theory and thoroughly grounded in the practical applications to surveying, mapping and timber estimating. The present stage of development of the use of aerial photography places a premium on the experienced ground cruiser with an intimate knowledge of local forest conditions and the ability to assimilate quickly the rudiments of interpretation from a stereoscopic model. There would appear to be only a very limited field (if any) for the highly trained photogrammetric engineer except in the research branch of public agencies and in the teaching field. For the present even the largest timberland operators and consulting firms will continue to look to the aerial survey firms for mosaic work, topographical mapping and other services of the skilled photogrammetrist.

There is another phase of photogrammetry which is worth some consideration in light of the forest industries' need for periodic photographic recoverage for "spot" coverage of limited areas following cutting, insect epidemics, fire, etc., for coverage of isolated small areas in an irregular or broken ownership pattern, and for large scale coverage of small isolated areas for planning work. This phase is the production of aerial photography with company equipment and personnel.

Some firms in the forest industries own and operate aircraft suitable for photographic work which are based in or near the areas involved. With suitable personnel on its staff available for part-time photography work, such a firm could obtain aerial photography with little loss of time involved in the "stand-by" classification or in "ferrying" which are large factors in the present cost of contract photography.

The extensive use of aerial photography in prospect for the forest industries points to the feasibility of such a plan, and to a quick realization of the necessary investment in equipment. The availability of men with Service training as photographers and photographic pilots is another factor in favor of such a plan.

Conclusions

1. Aerial photography as a forestry and engineering tool is rapidly gaining acceptance among the forest industries of the Northeast.
2. The principal use of aerial photography by the forest industries today is for planimetric forest type mapping and for reconnaissance type timber volume estimating.
3. The photogrammetry field in the forest industries today is primarily one for the forester or forest engineer with an intimate knowledge of local ground and forest conditions and basic photogrammetry training, rather than for the professional photogrammetric engineer.
4. The use of company aircraft, personnel and photography equipment for producing aerial photography offers promise in view of the forest industries' frequent need for "spot" coverage of isolated areas.

Marshall S. Wright

I am of the opinion that the minimum qualifications expressed in the Report to the Society by its Civil Service Committee, dated November 14, 1946, can be well substantiated by those who hire photogrammetric technicians, and I believe they could well be used by educators in the preparation of engineering curricula. This Committee report has been, or soon will be made available, I believe, to the entire membership of the Society for review and comment. A review of this report will constitute a complete understanding of my viewpoint on this subject.

I would like to call your attention to an article appearing in the July-September 1946 issue of *Surveying and Mapping,* by Prof. George H. Harding of Ohio State University, entitled, "A New Era in Surveying and Mapping Curricula." It seems to me that this article is very pertinent to the subject.*

Considering the short time usually available for the study of photogrammetric subjects, which in some schools is an elective course, it seems essential—provided the student proposes to embark upon this type of a career—that educational institutions concentrate upon the fundamental theories of photogrammetry; otherwise, if the student is not well grounded in the mathematics and optical principles in connection therewith, he is seriously handicapped when he is assigned engineering problems based upon a knowledge of the theories involved. If time permits or the curricula can provide for practical application of theory, it is, of course, more desirable.

* Reprinted, pp. 395–401.

The best and most concise answer I can give to question three is: *It all depends*. If his services were required solely on research or development work, I would want the best trained man I could get, and obviously I would assume he would have to have a college trained background. By the "law of averages" the chances are far better of securing a capable, well trained man possessing the necessary educational prerequisites from those with college degrees, but nevertheless there are many other characteristics such as leadership, initiative, ingenuity, and industry, which unfortunately are not acquired in school, and are no more often possessed by the college man with his "formal" education than by the non-college man who by hard work, perseverance, and a considerable amount of intestinal fortitude, has acquired the fundamental educational requirements necessary to qualify for his job. This is not to say that there are not many college graduates who possess all or most of these qualifications, as there are; and when they do have that ideal combination of educational requirements and personal characteristics they are usually very prominent and outstanding in their profession.

If I were hiring a great many men for an engineering project, and was unhampered by pre-established criteria, I would endeavor to select them in the following order:

1. College trained men possessing demonstrated initiative, ingenuity, resourcefulness, industry; and last but not least in importance, a pleasant personality and an indication of a cooperative spirit.

2. Non-college trained practical men possessing the necessary amount of specific knowledge to perform their assigned functions, plus a demonstration of their *leadership*, with the other attributes above mentioned.

The above two groups would comprise the administrative and supervisory technical personnel. It must be recognized, however, that their distinctive individual characteristics and capabilities are not "inscribed on their brows," and no yardstick other than past records and experience would aid in their selection; also, they would probably be men thirty or more years of age.

In addition to this "overhead" group, the bulk of an engineering organization would have to consist of persons whose only manifestation of capability would be their educational background. Their latent and possible potential characteristics would have to be demonstrated after employment.

In closing, I do want to stress one point, and that is that there is no stigma attached whatsoever to a person merely because he is not a "born leader" or does not prefer to assume any administrative or supervisory position. Many of the most brilliant and most capable technicians prefer to concentrate all of their effort on the solution of scientific problems, and/or the production of material. In fact, without the assistance they render, the work of all others is futile.

I am not answering your letter in my official capacity as a representative of the Department of Agriculture, but merely as a member of the American Society of Photogrammetry.

*Gilbert G. Lorenz, Chief, Photogrammetric Branch, Engineer Research and Development Laboratories, Fort Belvoir, Virginia**

There is probably no career in which a broader grasp of science and its many engineering applications is more necessary than that of research and development. To specialize in a field such as photogrammetry demands not only a thorough theoretical and practical background in all phases of photogrammetry

* Cleared for publication by the War Department Public Relations Division.

but also a thorough theoretical and practical background in the basic sciences and the principles of engineering. Unfortunately, not all those engaged in research and development have all the prerequisites. The demand for engineers has been so great that not enough men of the required education, experience and ability are available to fill the many openings. Employment of those who lack some of the essentials and on-the-job training have been found necessary.

Education for a career in any field of engineering cannot be completed by an engineering degree. Education by experience and practice is a necessary adjunct to formal college instruction. Furthermore, constant study of engineering literature is essential to keep abreast of progress and is an important phase of advanced education. Research and development is no exception and the field of photogrammetry falls right in line, not only with respect to its particular specialized field but also to general engineering knowledge.

Because of the necessity for a broad engineering background to draw upon in the design and development of photogrammetric equipment and methods, a full course in basic engineering principles is essential. Particular emphasis should be placed upon such subjects as optics, optical design, principles ofphotography, machine shop practice and design, electronics and statistics. All related mapping subjects are required because of the interrelation and interdependence of photogrammetry with other phases of mapping. Such courses should include surveying in all its forms, astronomy, geodesy, geology, cartography, lithography and map reproduction.

It is felt that a college course preparatory to a career in research and development in photogrammetry should stress the fundamental theories of photogrammetry, principles employed in the design and operation of photogrammetric equipment, and the general methods employed in producing maps by photogrammetry. Laboratory periods should be devoted to familiarization and practice of the most salient principles of photogrammetry, inspection and general familiarization with some of the simpler photogrammetric equipment, and a little practice in using some of the simpler photogrammetric procedures. Analytical methods are needed for the proper understanding of mechanical methods and are an essential part of the fundamental theories. However, analytical methods should not be overstressed and studied as a complete mapping method, but should be used primarily as a tool to explain the theory of photogrammetric instrumentation. A knowledge of the basic principles of analytical methods should enable the novice to learn the practical applications of particular instruments in a relatively short time. It would appear that time would not permit the student to become proficient in the use of any one instrument or method in a college course, nor is this desirable. A more general knowledge of photogrammetry and its various application would seem more appropriate.

Obviously, a curriculum as outlined above could not be contained in a four year undergraduate course. The undergraduate years should be devoted to basic studies, including the basic principles of photogrammetry, engineering, surveying and other allied mapping subjects. The graduate year should be devoted to such advanced studies as optical design and principles used in the design and operation of photogrammetric equipment.

A graduate of such a course certainly would have all the fundamentals at his disposal for the development of new photogrammetric equipment, modification and improvement of present equipment, and research into new and untried photogrammetric principles and methods. Practice and experience, however, are essential before one's education is sufficiently well rounded to be of much practical value. Operation of photogrammetric equipment and use of photogrammetric methods must be learned in the apprentice stage after graduation. With a few years' practical experience following a specialized photogrammetric engineering curriculum, plus natural ability, opportunities for a successful career of research and development in photogrammetry should be abundant.

Lewis A. Dickerson, Army Map Service

First of all, it should be stated that anything I say on the subject represents only my own personal opinion and in no way reflects the official attitude of the Army Map Service.

I shall answer your second and third questions first and together since they are closely related. I believe the colleges should stand by fundamentals principally, only bringing in enough of the practical side to illustrate the application of those fundamentals. For example, a parallel can be shown in Civil Engineering. Considerable study is given in such a course to stress analysis. The laboratory work, however, is usually confined to design of one or two structures. It is not necessary to design in both steel and aluminum to illustrate the fundamentals of strength of materials and stress analysis. Likewise, it is not necessary to compile maps by both Multiplex and Aerocartograph to illustrate the application of stereophotogrammetry. It will be gathered from this that I would prefer to employ a college trained man who had had instruction in fundamentals of surveying, mapping, cartography, and photogrammetry rather than one having specific training in some given instrument or method.

I can only answer your first question regarding course content in a general way at this time. Outline of a specific course would require further study and I doubt that I am qualified to do it in other than general terms anyway. So, in general, I believe the first two years of such a course should be about the same as the usual first two years of an engineering course. That is, the basic sciences and usual higher mathematics should be covered. Elementary surveying and drafting would also be appropriate to the first two years. Going into the last two years, they should at least include the following: practical astronomy, geodetic surveying, elements of cartography, analytical photogrammetry, and some laboratory work in application of photogrammetry. Related courses in geology and geography would be appropriate as well as a judicious amount of the social sciences and cultural subjects.

TRAINING IN PHOTOGRAMMETRY BY THE U. S. NAVY HYDROGRAPHIC OFFICE

Sidney Sherman, Photogrammetric Engineer

DURING the period from July 1946 to July 1947, approximately 75 persons were given instruction in photogrammetry at the Hydrographic Office. The extent of this training to individuals or groups varied from one week to twelve weeks' duration. Since the Photogrammetry Section with its small staff was constantly being called upon to give this instruction, often on short notice, it was recently found necessary to design a course in Photogrammetry, consisting of a series of lectures and exercises, primarily for the training of U. S. Navy and civilian personnel connected with the Hydrographic Office. The course stresses the requirements and methods of mapping from aerial photographs as used by the Navy for the preparation of hydrographic charts.

The type of instruction given and the emphasis placed upon the various phases of the subject differs according to which of the following groups the trainee belongs; 1) hydrographic survey officers, 2) aircraft pilots and photographers, 3) visitors from foreign countries, 4) civilian employees. During the period July 1946 to July 1947 approximately 20 survey officers were given two to four weeks of instruction in photogrammetry with emphasis upon control requirements. One week courses were given to more than 30 Navy pilots and aerial photographers, stressing photography and flight specifications. Seven South American Naval officers were given complete instructions in photogrammetric mapping methods. Of these officers, four are from Argentina, two from Peru and one from Colombia. In addition to these officers, six Chinese Army officers were given training specifically in the operation of the K.E.K. Stereoscopic Plotter. Several civilian employees were also trained in the operation of stereoplotting instruments during this period.

It is not necessary for every person connected with aerial photography, surveying or map compilation to be an expert in all of the technical phases of the subject of photogrammetry. All of these persons, however, should have an understanding of the basic principles of the subject and of the particular role which he plays in obtaining the final map. In view of this, an attempt is made to stresss the relationship of aerial photography to surveying, and the importance of both in the process of map compilation.

Photogrammetry is primarily a study for application. The theoretical basis of the subject lies in the fields of physics and mathematics. Its recognition as a separate field of study is due to the numerous valuable practical uses which have been found for it in many fields including art, archeology, astronomy, agriculture, crime detection, surgery, census surveys, electronics, engineering, forestry, geography, geology, hydrography, photo intelligence, surveying and mapping. With a wider knowledge of the subject, undoubtedly more applications will be found in these and other fields. By far, the widest application of photogrammetry so far has been in the field of surveying and mapping, and it is with this application that this office is, at the present time, primarily concerned.

The rapid development of the airplane in recent decades has brought about a revolution in the science of surveying and mapping from photographs but it also brought about many new problems to be solved. Better cameras, more sensitive photo materials, new instruments and procedures had to be invented and developed. Many of these developments have already come about. Many problems, however, remain to be solved and many of the solutions to these problems are now in the experimental stage; as for example, the development of airborne equipment to obtain horizontal and vertical control on each mapping negative, the development of accurate camera stabilizing equipment, or, for example, the development of airborne means of determining underwater depths in shallow waters. Research on the part of the government, industry and colleges can make valuable contributions toward the solution of these problems.

The following is an outline of the material covered in the course in photogrammetry given at the Hydrographic Office. If four weeks or less are available for instructions, only the material in Part I is covered. If more time is available, the subjects listed in Part II are also taken up. This course in general is meant for persons new to photogrammetry, however, from time to time more detailed training is given, for example, in the operation of a stereoplotting instrument, to persons already familiar with the basic principles of the subject.

AN INTRODUCTORY COURSE IN PHOTOGRAMMETRY FOR MAPPING
COURSE OUTLINE

Part I—Lectures A–M

A. Introduction and Scope of Course.

B. Maps and Charts.

1. Definitions.
2. Types and Purposes.
3. Characteristics.
4. Scale.
5. Map Projections and Coordinate Systems.
6. Accuracy.
7. Conventional Signs and Symbols.
   Reading Material.
   Exercise #1—Quiz.

C. Topography—Elevation and Relief.

1. Topography.
2. Elevation.
3. Relief.
4. Methods of Representing Relief.
   a) Contours b) Hachures c) Shading d) Color Gradients e) Form Lines.
5. Contours.
   a) Definition b) Contour Interval c) Contours and Slope d) Characteristics of Contours.
6. Summary.
   Reading Material.
   Exercise 2a—Quiz.
   Exercise 2b—Problems in Contouring.

D. Standards for Photogrammetric Compilation of Maps.

1. The Development of Aerial Mapping.
2. The Status of the Topographic Mapping of the World.
3. Map Making Agencies.
4. Scales of Military Maps.
5. Source Material.
6. Theater Areas.
7. Operational Index.
8. Sheet Numbering System.
9. Standard Specifications and a Sample 1/25,000 Manuscript Sheet.
   Reading Material.
   Exercise #3—Quiz.

E. The Place of Aerial Photos in Surveying.

1. Aerial Photos vs. the Planetable.
2. The Principles of Surveying.
3. Aerial Photos vs. the Topographic Map.
   Reading Material.
   Exercise #4—Quiz.

F. Aerial Cameras and Accessories.

1. Principle.
2. Types.
3. Aerial Camera Lenses.
4. Shutters.
5. Strip Camera.
6. Focal Plane.
7. Fiducial Marks.
8. Film Magazine.
9. Cameras in present day use.
10. Accessories.
    a) Bubble Level b) View Finder c) Intervalometer d) Color Filters e) Stop Watch.
11. Aircraft Camera Mounts.
    Reading Material.
    Exercise #5—Quiz.

G. Aerial Photographs: Types—Filters—Film and Paper.

1. Types.
   a) Obliques b) Verticals c) Composite d) Trimetrogon.

2. Filters.
3. Characteristics of Photo Materials—General.
4. Film.
5. Paper.
   Reading Material.
   Exercise #6—Quiz.

H. Aerial Photographs: Characteristics—Scale and Relief.

1. General.
2. Scale.
3. Displacement due to Relief.
   Reading Material.
   Exercise #7—Problems.

I. Aerial Photographs: Tilt Displacement.

1. General.
2. The Effect of Tilt.
3. Methods of Tilt Determination.
   Reading Material.
   Exercise #8—Problem in Tilt Determination.

J. Aerial Photographs: Specifications—Indexing and Inspection.

1. Specifications.
2. Indexing.
   a) Purpose b) Identification c) Methods.
3. Inspection.
   Reading Material.
   Exercise #9—Problem in Indexing.

K. Stereovision.

1. General.
2. The Human Eye.
3. Binocular Vision.
4. Stereoscopic Parallax.
5. Stereoscopic Fusion.
6. Observing Relief in Aerial Photographs.
7. Stereoscopes.
8. Exercises in Stereovision.
9. Correct use of Stereoscope.
   Reading Material.
   Exercise #10—Practice Stereovision.

L. Aerial Photographs: Mapping Methods and Control Requirements.

1. The Mapping Problem.
2. Solutions to the Mapping Problem.
   a) Mathematical Solution b) Graphical Solution c) Optical Solution.
3. Stereoscopic Plotting Instruments.
   a) The Stereocomparagraph b) The K.E.K. c) The Multiplex d) The Stereoplanigraph.
4. Control Requirements.
   a) Importance b) Control Density c) Basic Requirements d) Identification
   e) Control Planning. f) H.O. Control Requirements.
   Reading Material
   Exercise #11—Problem in Control Planning.

M. Radial Line Methods of Mapping.

1. General.
2. Purpose.
3. Theory.
   a) Radial Line Principle b) Relief & Tilt.
4. Requirements.
   a) Photography & Compilation b) Horizontal Control.
5. Methods of Radial Line Triangulation.

6. Procedure.
    a) Preparation of Base Sheet b) Preparation of Photographs
    c) Establishing "Photo Control" d) Plotting the Planimetry.
    Reading Material.
    Exercise #12—Compile a Planimetric Map.

Appendix A—Outline and Reading Material for PART II—Lectures N–W.
Appendix B—Bibliography.
Appendix C—Required Equipment.
Appendix D—Examination Questions.

PART II—LECTURES N–W

N. Photo-Interpretation.
O. Stereo Plotting Methods: Parallax and Elevations.
P. Stereo Plotting Methods: The Stereocomparagraph.
Q. Stereo Plotting Methods: The K.E.K. Stereoscopic Plotter.
R. Stereo Plotting Methods: The Multiplex and Stereoplanigraph.
S. Supplementary Control with the Camera Transit and Photo Transit.
T. Mosaic Mapping.
U. Oblique Mapping.
V. Tri-Metrogon Mapping.
W. Planning a Photo Mapping Project.

This course in Photogrammetry is but one example of what some of the Federal Agencies are doing in the way of training the personnel needed to carry out their own programs. In view of the wide application of the subject, however, colleges and engineering schools throughout the country can perform a valuable service by making such instruction more readily available.

As far as the college student is concerned, the possibility of job opportunities in the field is an important consideration in determining whether or not to select a specialized course such as photogrammetry. It should be the task of the American Society of Photogrammetry to survey and publicize the job opportunities in the field. A survey might possibly be attempted to cover commercial companies and government agencies, federal, state and local to find the answers to questions such as the following:

1. The total number of companies and Government agencies employing photogrammetrists?
2. The total number of photogrammetrists employed by each company or agency in 1940?
3. The total number of photogrammetrists employed by each company or agency in 1947?
4. The expected number to be employed in the future?
5. Increase or decrease?

Some conclusions concerning the value of having a few colleges in the country offer courses toward a degree in Photogrammetric Engineering may be drawn from such a survey.

There are many jobs requiring some training in photogrammetry, other than those as full time photogrammetrists. Specialists such as pilots, navigators, photographers, field surveyors, geologists, foresters, agriculturists, astronomers, hydrographers, and civil engineers, all would benefit from a knowledge of the principles of photogrammetry. Such basic information should be readily available at all colleges.

It would be of great benefit to the profession of photogrammetry as well as to the engineering profession in general if photogrammetry would be included as an integral part of every college course in surveying and if in addition at least one special course in photogrammetry were to be offered at every Engineering College. If this were done there would certainly be less chance of having surveyors or civil engineers making the error of taking measurements on mosaics as if they were maps. Furthermore, there would be considerable saving in both time and money if all engineers knew exactly when and how aerial surveys could be advantageously substituted for, or used to supplement, ground surveys. Both the advantages and limitations of aerial photos for surveying purposes should be general knowledge among engineers.

The value of photogrammetry to the studies of geology, soils and forestry is of considerable importance and the subject should certainly be included as a recommended course for a student seeking a degree majoring in one of those sciences.

As to the content of college courses in photogrammetry, this will of course vary in emphasis and in detail depending upon whether it is an advanced course or an elementary one and whether it is stressing surveying, mapping, mosaics, photo-intelligence, geology, forestry, soil studies or some other aspect of the subject.

All courses pertaining to photogrammetry, should include as a minimum, information concerning;

1. Basic characteristics of photographs, perspective qualities, relief and tilt displacements.
2. Elements of stereoscopy
3. A simple graphical method of mapping.

Where more time is available, the other material as listed in the outline above can be included, and of course, advanced courses in the subject could concentrate more on theory, equipment and procedures.

Photogrammetry is still in a youthful stage of development and is not yet being used to a maximum possible advantage either by private industries or by local, state or federal governments. It has not yet received sufficient recognition by colleges, possibly due to inertia or lack of information concerning the valuable applications of the science, or of limited information regarding job opportunities in the field. Perhaps informing more people as to what it is, will stimulate the greater application of such knowledge and thereby bring about a better understanding of the geographic basis of the world in which we live.

V. Van Keuren

This discussion is written by me as a member of the Society and not as a representative of the U. S. Naval Photo Interpretation Center.

Research and development in all branches of engineering has been given a great impetus during World War II and photogrammetry has been no exception, however, for the most part it is my belief that many colleges and universities have not kept fully abreast with photogrammetry and its greatly expanded use in mapping and surveying. The need for trained and experienced personnel who are capable of devising new procedures, improving techniques and designing new apparatus for photogrammetry is ever present, in both government and civil companies. A suggested course in an engineering college to better fit a graduate for photogrammetric work should include in addition to the regular engineering subjects, an advanced course in Analytical Geometry, Advanced Surveying, Geodetic Control, Practical Astronomy, Optics, Physics and Drafting (Machine Design and Topographic). Also all phases of photogrammetry ground and air, theory of stereo and stereo instruments. It is to be highly recommended that at least one summer shop course consist of a thorough familiarization with all available photogrammetric instruments and apparatus in current use by various federal and civil companies.

In my opinion colleges should thoroughly stress the fundamental theories of photogrammetry and that the specialized applications should be acquired by graduates after they are employed. The field of photogrammetry is very broad and the needs of the organization hiring photogrammetrists will determine the particular branch in which they will work. A photogrammetrist who possesses special knowledge, skill or training is certainly a valuable asset to many engineering organizations but the combination of a good general engineering background plus this special knowledge, skill and training can go a long way to make a man outstanding in this field.

Photogrammetry is a highly specialized phase of mapping and surveying and requires a type of person who possesses ability, personality and a most cooperative spirit, and although probably a formal engineering education plus specialized training and experience will materially help this person obtain a high degree of usefulness, it is very important to keep in mind the fact that a very large amount of the development of photogrammetry has been accomplished by personnel who started in practically an apprentice status without the benefit of a formal engineering education, who by long hard work acquired knowledge and experience that has placed them in a very enviable position in this field. A great deal depends on the individual and in choosing personnel for various positions in photogrammetry, consideration is certainly given to past experience and accomplishments but the graduate possessing a good engineering background, a willingness to work and a desire to continue to study should certainly accomplish much in this very important phase of the engineering profession.

Additional Comments, Marshall S. Wright

I must say, as one who has employed a great many men during 25 years of surveying and mapping experience, that I have often been disappointed in the attitude taken by a great many young college graduates in the assumption of their first job. Many of them, particularly on field assignments, evidence the impression that they feel it is beneath their dignity to do manual survey work; they are often, I am sorry to say, clock watchers and malcontents; while on the other hand, I have often found that bright young high school students make up a better field surveying organization; their morale is high; they don't expect too much, and every job is an advance over another. Furthermore, they admire and respect an instrument man, and usually make very apt pupils.

TRAINING ACTIVITIES OF THE NAVAL PHOTOGRAPHIC INTERPRETATION CENTER*

J. W. Gardner and S. M. Johnson, Training Department

Aerial photographic interpretation and photogrammetry are "precision tools" of vital importance to mankind's existence. In a war today, a nation which failed to use intelligently the vital information gleaned from aerial photographs, would just as certainly face defeat as if it depended solely upon smoke signals for communications.

As a result of wartime training, there are at present in the United States hundreds of men and women well schooled in the sciences of photo interpretation and photogrammetry. Between January 1942 and August 1945, the U. S. Naval Photographic Interpretation Center trained over eight hundred Naval, Marine Corps and Army personnel. Since the cessation of hostilities over fifty officers of the regular Navy, Marine Corps, and Army have been graduated

* Released for publication by Navy Department, Office of Public Information.

from this Center. The abrupt end of hostilities, the expedited disintegration of our armed forces, and the rapid healing of "war ravaged" America have again created a lethal apathy towards military preparedness. The many personnel trained at this Center during the war were all reserve officers. Thus their services and valuable wartime experience, were lost upon demobilization. The main purpose for the intensive training program now carried on at P.I.C. is to provide trained officers to fill the vacancies created when wartime photo interpreters were discharged.

In November 1938, the Chief of the German General Staff, General Oberst Baron Werner von Fritsch said, "The nation with the best photo reconnaissance will win the next war." By 1940 Germany led the world in military photography. The Nazi drive in the spring of that year, culminating in the battle of France, had been prepared for in advance by intensive study of aerial photographs. The Allies, up to the time of Dunkirk, had given little or no thought to photographic interpretation, relying solely upon information obtained through conventional intelligence channels. However, when the Allies were pushed from the continent at Dunkirk, previously developed sources of information were stilled. The British were then forced to develop aerial photography as their prime means of obtaining information.

In the spring of 1941, the U. S. Naval Attaché in London requested that a competent officer from the Bureau of Aeronautics be sent to London to study the British Photographic Interpretation Organization. This assignment soon led to a request that additional officers from the Navy and Marine Corps be sent to England to study the British techniques. Consequently, on September 12, 1941, the Chief of Naval Operations recommended the establishment of a school for Photo Interpretation at the U. S. Naval Air Station, Anacostia, D. C. Despite many obstacles, the U. S. Naval School of Photo Interpretation opened its doors on January 5, 1942 to a class of twenty-eight Naval and Marine Corps officers. Although the first six classes numbered twenty-eight officers each, the demand for PI's increased so rapidly that facilities had to be expanded and subsequent classes trained between fifty-five and sixty officers.

Personnel trained in photo interpretation and photogrammetry contributed materially to the successful culmination of the war as attested in reports and statements issued from many and varied sources. The recognition received is well illustrated in the following statement issued by Admiral R. K. Turner, while serving as Commander Amphibious Forces, Pacific Fleet: "aerial photography and photographic interpretation have been the primary sources of intelligence in the Pacific War. Their importance cannot be overemphasized."

Shortly after the cessation of hostilities the Photographic Interpretation Center was reorganized on a Civil Service basis. Many former photo interpreters now occupy civilian positions at this Center as training specialists, research analysts, etc. Since reorganization, P.I.C has graduated four classes in photographic interpretation and three in photogrammetry. Each class is under instruction for fifteen weeks, with new classes convening every sixteen weeks. In addition to the fifteen week courses of instruction, given to regular officers of the Navy, Marine Corps, and Army, the following training is offered: reserve officer correspondence courses; a two week course for reserve officers on annual training duty; a four to six week course to train enlisted personnel as aides to photo interpreters and photogrammetrists; and special courses of instruction, taught by instructors from this Center, in training programs offered by other military organizations.

Syllabuses for the fifteen week course in photographic interpretation and the fifteen week course in photogrammetry are given below. These courses are subject to continuous revision and reorganization. For reasons of security certain subjects have been omitted from this printing.

OUTLINE OF THE FIFTEEN WEEK PHOTOGRAPHIC INTERPRETATION COURSE

Introduction to Photographic Interpretation. The purpose and scope of the course are summarized. The value of photographic interpretation and its contribution to over-all intelligence is discussed and the role of photo interpretation in World War II is reviewed. New developments in photographic interpretation and new demands on the photo interpreter are enumerated for the students consideration.

Aircraft Used for Photo Reconnaissance. Discussion of the types of planes used for aerial photography with emphasis placed on the capabilities and limitations of each for flying various types of photographic missions.

Cameras Used for Aerial Photography. Demonstration of the manual and electrical operation of various aerial cameras. The capabilities and limitations of each camera are pointed out and the student is made cognizant of the fact that care should be exercised in selecting the right camera for the job.

Mathematics of Photographic Interpretation. A review of mathematical relationships and procedures that are basic to photo interpretation.

Drafting. Instruction in the care and manipulation of drafting instruments that are commonly used by the photo interpreter including, lettering sets, contouring pens, ruling pens, etc. Instruction is also given in the drawing of symbols, construction of legends, bar scales, north arrows, title blocks, and the use of acetate and acetate ink.

Reproduction. Lectures and demonstrations covering the various methods of reproduction followed by a trip through various activities engaged in reproduction work. Instruction includes a discussion of the organization of field photographic laboratories.

Map Projections. Comparison of the various types of map projections including the Lambert Conformal, Polyconic, Conic, Mercator, Azimuthal Equidistant, etc., and the limitations and uses of each type.

Map Signs and Symbols. The study of various types of maps and charts in order to become familiar with the conventional and military symbols used.

Computation of Scales. Exercises in computing bar scales and representative fraction scales, and in changing photo scale to chart scale and vice versa.

Maps and Map Substitutes. Characteristics and uses of various types of maps and the employment of photos and photo mosaics as map substitutes. This instruction also covers the proper determination of distance and direction on a map.

Construction of Overlay. An overlay is prepared which serves as a review of previous instruction in drafting and map reading. This overlay is used later in the course as the base sheet for a defense interpretation report.

Titling and Scale Determination of Aerial Photography. The proper titling of reconnaissance and mapping photography to assure recording of all pertinent data, and the three common methods of photographic scale determination:

Plotting and Flight Planning. Determination of number of runs over an area to obtain complete coverage, number of exposures per run and total number of exposures, overlap of photos, intervalometer setting, scale, etc. Emphasis is placed on the correct plotting of photographic coverage to assure accurate indexing of all photography.

Stereoscopy. A study of the various methods of viewing photographs in three dimensions to obtain depth perception. Instruction includes the use of stereograms, vectographs, anaglyphs, etc., and practice in seeing stereoscopically with the unaided eyes.

Tone and Shadow. By a study of selected aerial photos it is demonstrated how shadow, and differences in tone, texture and color serve as aids to interpretation.

Physiographic Forms and Vegetation Types. Instruction, accompanied by lantern slides and stereograms, in the classification and recognition from aerial photos of terrain and vegetation types.

Contouring from Aerial Photographs. Instruction and practice in the representation of terrain features by contour lines through stereoscopic study of aerial photos employing the principles of logical contouring.

Mosaic Construction. Instruction and practice in the cutting and assembly of aerial photos to form an uncontrolled mosaic. The military uses and limitations of such a photomosaic are discussed.

Military Grids. Instruction in the basic principles and merits of various military grids, and the utilization of such grids by photo interpreters and in military operations.

Camouflage. Lectures covering the definition of camouflage, instances in which it is used, purposes, whom it is likely to mislead, its importance from the photo interpreters standpoint, the correct interpretation of camouflage, techniques of the camoufleur, and the uses and value of camouflage detection film, and aerial and ground photographs. The course concludes with class problems on the interpretation of camouflaged installations.

Three-Dimensional Terrain Model Construction. Lectures, demonstrations, and training films relative to the processes, techniques, and materials used in the construction of a terrain model and the discussion of the value of such models in military operations. Each student prepares a contour map from aerial photos from which he constructs, paints, and textures a terrain model, scale 1:7500, of an area in which an amphibious landing might be contemplated. The best student model is selected and from this a finished, three-dimensional rubber terrain model is constructed, each step of the operation being demonstrated before the class.

Geometry of Vertical and Oblique Photographs. A study of the methods used in determining the true ground position of objects on vertical and oblique photographs. Both graphic and optical methods of rectification are discussed and demonstrated.

Flak Interpretation. Covers the history of the development of antiaircraft defenses, a discussion of the principle weapons and their capabilities, the tactics and disposition of flak batteries, and the techniques of interpreting antiaircraft defenses on aerial photographs. Lectures are presented on the classification and diagnostic features of modern AA weapons.

Flak Analysis. An analysis of enemy antiaircraft defenses in the vicinity of targets subject to air attack, for the purpose of determining the approach and withdrawal routes which will keep plane and personnel losses from enemy flak to a minimum. Lectures and problems are given on the most up to date methods of flak analysis and the construction of flak analysis charts.

Radial Line Plot. Lectures cover the definition, purpose, use, and method of construction of a radial line plot. A radial line plot is constructed by the class. The course is designed to acquaint the student with various aspects of photogrammetry along with such other subjects as the geometry of vertical and oblique photos, use of the stereocomparagraph, etc. These subjects are given in much greater detail during the fifteen week course in photogrammetry.

Military Defenses. This course entails the study of defenses encountered in all theaters of operation in World War II as well as new trends and developments in military defenses. Duplicated and individual stereo demonstration photographs are used in conjunction with blackboard diagrams, sketches, and motion pictures. Tactical interpretation is discussed by a specialist lecturer.

Color Photography. This course covers early developments and the more resent history of color photography. The three most outstanding developments with three color registration, Technicolor, the Troland Monopack process, and Kodachrome are discussed in detail. Special cameras, methods of exposure, and inbibition printing are explained and illustrated as applicable to both still and motion picture work.

Night Photos. Lectures and examples covering the various methods of night photography and the interpretation problems peculiar to this special type of photograph.

Electronics. Lectures and demonstration of current means of identifying various electronics installations on aerial photos.

Report Writing. Lectures on standard procedures for writing military photographic interpretation reports, followed by the photo interpretation of a heavily defended area and the preparation of a written report and defense overlay of the area. This course is designed to prepare the student for later phases of the course in which detailed interpretation reports are required.

Stereocomparagraph. Detailed instruction and practice in the theory and use of the stereocomparagraph. This is a familiarization course designed to prepare the student for such work as the determination of heights of objects, underwater depths, contouring of aerial photos, etc.

Determination of Object Height. Lectures and problems in the determination of heights of objects from vertical aerial photographs by measurement of parallax and by measurement of shadow lengths. The former involves the use of such instruments as the stereocomparagraph, the latter method involving the relation of the height of the object to its shadow as seen on an aerial photo when the date, time, latitude and longitude of the photography are known.

German Training Photos. A short course dealing with selected examples of photographs used by the German Air Ministry in a demonstration series for aerial photo interpreters.

European Intelligence. A lecture on additional intelligence functions which are related to photographic interpretation.

Industry. Detailed instruction in the recognition from aerial photos of each of the major industries. Lecture material is supplemented by motion pictures, selected aerial photos, and field trips to industrial plants.

Target Analysis. Lectures, exercises, and problems covering the introduction to target analysis, functional analysis, target plan construction, determination of shadow scale, industrial damage assessment, damage repair, and limited damage.

Industrial Analysis Problem. Teams consisting of two students each are issued photos of unidentified industrial plants. Using the information and technique learned in earlier classes covering industry, the students are required to identify and prepare a complete interpretation report of their area using the facilities of the Photo Interpretation Library and any other source of information they wish to consult.

Industry Seminar. Each student team assigned an industrial problem presents its findings to the class, explaining the factors used in identifying the particular industry studied and giving all information incorporated in their report, etc.

Ship Identification and Harbor Analysis. A study of the national characteristics of ships and the functional design of ships by classes, highlighting characteristic features to be used in the aerial photo interpretation. Ships of the U. S. postwar fleet are studied as well as those of other nations.

Harbor installations are studied from the viewpoint of photo interpretation information as to specific activity going on.

Aerial Reconnaissance and Site Inspection. After covering industry, military defenses and shipping, the class is taken on an aerial reconnaissance trip over similar objects and installations. After viewing defense installations, shipping and industrial plants from the air a ground inspection trip is made of the same areas.

Underground Factories. This course reviews the history of underground plants, examines their strategic and tactical advantages, their geological environment and seeks to establish intelligence procedures for the location and analysis of such installations with particular interest in the applications of aerial photography to the problem. The course concludes with a problem in which the student with the aid of a map and several unannotated prints, is expected to locate an underground factory, its entrances, communications, possible tunnel arrangement, its removed spoil, stores and other related phenomena.

Guided Missiles. Included in the treatment of this subject is a résumé of the German Guided Missile Campaign of the last War and a summation of its effectiveness and implications for the future. Photography of German missile installations is examined and interpreted.

Urban Area Analysis. An analysis of the significance of urban attacks in World War II, the importance of urban areas as targets in future warfare, and the objectives of urban area photographic intelligence. Application of urban analysis to the offensive and defensive aspects of military operations. Discussion and problems in pre-attack analysis including zoning, building density, structural content, fire breaks and topography.

Aircraft and Airfields. A study of the national characteristics and functional design of all types of aircraft. Lecture material including the requirements of various types of aircraft reports, methods, aids and expedients used in aircraft interpretation, and methods of airfield identification and requirements of airfield reports. Problems are given in which the student writes an aircraft and airfield report and applies all the information gained in previous instructions. The course is concluded with a lecture on the relation of aircraft and airfield interpretation to the other fields of photo interpretation and intelligence.

Aircraft Inspection Trip. One day is devoted to a guided tour of an aircraft plant in the Washington area engaged in the manufacture of standard aircraft, jet planes, guided missiles and rockets.

Underwater Depth Determination. Discussion of the importance of accurate water depth data to the success of an amphibious operation, followed by a study of the various methods of determining underwater depths from aerial photographs.

Beach Interpretation. A brief coverage of all phases of Photographic Interpretation required in amphibious operations (with the exception of quantitative depth determination). The subject is treated in the following divisions:

1. Lecture material is given covering:
   a. Amphibious force organization.
   b. Phases of an amphibious operation.
   c. Mission of intelligence and photo interpretation in each chronological phase.
   d. Type of intelligence material required for each special group engaged in the operation.
   e. Preparation and use of graphic material for briefing and operational use.
2. Motion pictures showing amphibious organization and operation.
3. Training problem.
   a. Preparation of beach report on a given section of coast.
   b. Preparation of mosaic and overlay, using comparative cover.
   c. Examination of results using ground photos.

OUTLINE OF THE FIFTEEN WEEK PHOTOGRAMMETRY COURSE

Projections. The first week of training is devoted to the study of map projections and grids. Instruction includes problems in the computation and construction of large and small scale Polyconic and Mercator projections, the construction of a military grid on a Polyconic projection, and the methods used in locating geographic control stations by geographic coordinates and checking by grid coordinates. This is followed by lectures, illustrations and demonstrations on other types of map projections, including the Lambert Conformal Conic, Azimuthal Equidistant and Gnomonic projection.

Cartography. Cartography introduces the students to maps and charts and is designed to give him a better understanding and appreciation of maps and charts and a working knowledge of their construction. The course is presented in a series of lectures, discussions, demonstrations, and class problems on cartography and related studies. Subjects covered include maps and charts, chart planning, construction and evaluation, natural scales, graphic scales, scale borders, latitude and longitude scale, units of measurement, soundings and fathom curves, generics, and various processes of reproduction. Other subjects included in the two week period of instruction are studies of tides, use of Hydrographic Office Pilot and Notice to Mariners, problems and exercises in computation and lay out of a Mercator projection from a known geodetic position, preparation of a chart specification sheet as a guide for drafting, and a review of all the steps in chart construction from the compilation of field surveying notes to the final reproduction of the chart. Near the end of the periods of instruction the class takes a trip through the U. S. Navy Hydrographic Office to see chart construction on a production scale.

Radial Line Plot. This problem is designed to introduce the students to some of the basic and elementary principles of photogrammetry. Several parallel overlapping flights of near vertical photographs are used in the radial line plot, and assembled on a military grid superimposed on a polyconic projection. The grid and projection were constructed during the week of instruction devoted to projections.

To give the plot the necessary control several geographic control stations are located on the grid by grid coordinates and checked by geographic coordinates on the projection and also identified on the photographs. Each student receives a complete set of photographs and is responsible for working the problem through to its successful conclusion. Two methods of assembly are illustrated; the acetate hand template and bristol board slotted template. The necessary points are picked on all the photographs and for two flights. Acetate hand templates are constructed and these two flights are assembled to illustrate this method of compilation. Then bristol board slotted templates are constructed for all the flights and these are assembled on the projection, holding to the geographic control stations. Template centers and picture points are transferred to the base sheet. From the total area of the plot, one third is selected for the preparation of a five color topographic sheet. The black, green and light blue sheets are prepared at this time, the detail being transferred from the photographs.

Contouring. During the next two weeks the brown sheet (contours) and dark blue color sheets are prepared, the contouring being done with the stereocomparagraph. First, the student is introduced to the operation of the stereocomparagraph by a lecture on the theory of the instrument and operation. This is followed with several exercises in spot readings and further exercises on height determination and form-lining. After the student is familiar with the instrument, he is introduced to the correction graph, and starts contouring the photos that will be used in his topographic sheet. When contouring is complete, and all the color separation sheets are prepared and checked, the best class map is sent out for color reproduction. Near the end of this week the students are given an introduction to and a demonstration of operation of the multiplex projector.

Geometry of Vertical and Oblique Photographs. This course covers at least one method of the analytical approach to vertical and oblique photographs. The analytical approach of the vertical photographs involves the computation of three elements of exterior orientation, namely, tilt, swing, and orientation relative to the survey data. The computations from the oblique photographs involves the three elements of exterior orientation, and in addition includes the computation of vertical angles for elevation determination. With this background the student is much better prepared to understand the theory of photogrammetric plotting instruments, graphic plotting and semi-graphic plotting.

New Photogrammetric Techniques and Developments. A specialist from the Photogrammetric Research Division of P.I.C. brings the class up to date on new developments in the field of photogrammetry. This is given in lecture and discussion form.

Trimetrogon Mapping. This problem is given to familiarize the student with the compilation of a small scale planimetric map from trimetrogon photographs, and covers a period of three weeks. The class assembles a completed small scale trimetrogon map, each student being responsible for compiling a section of the completed map. Each student is issued a certain number of photographs and must perform all the calculations necessary to transfer the desired information from the trimetrogon photos to a planimetric map. During the first part of the compilation the student works mostly independently on his own photographs selecting all the necessary points, determining tip and tilt, preparing paper templates in the rectoblique plotter, and constructing metal templates. Then he combines his metal templets with templets of the other members of the class, all the templets being assembled on a Polyconic projection that has been prepared by the students. The metal templates are controlled by several geographic control stations located on the projection and identified on the photographs. Upon completion of the laydown, the desired detail from the photograph is transferred to the base sheet, using vertical and oblique sketchmasters, and detail points for control. Before inking, the map is edited by the students and the necessary additions or corrections made. A title block is prepared and the map and title block are inked, final checking is made and the finished planimetric map sent out for black and white reproduction.

Surveying. This problem is given to acquaint the student with some of the methods of surveying, the use of the surveying instruments in the field, and some of the problems confronting the surveyor. The class is divided into teams, each team surveying a pre-established closed traverse laid out within the grounds at P.I.C. Upon completion of the field surveying each team performs the computations necessary to determine its error of closure.

Field Astronomy. A three week course in practical astronomy begins with a complete coverage of celestial mechanics, and time conversions. The student is given instruction and a considerable amount of practice in accurate time determination. This is followed with instructions on the operation and maintenance of the T-2 Wild theodolite. The students are then coached on the methods of making different types of azimuth observations and how to compute the results. Azimuth determinations are made by observing the sun, and by various methods of stellar observations. Upon completion of computations for results of the azimuth observations, the students are introduced to the prismatic astrolabe attachment for the T-2 theodolite. The students are instructed on the theory of the astrolabe, methods of computation, time recording, star list computations, auto collimation, and care and maintenance of the astrolabe attachment. Following this instruction the students simulate an actual observation in the classroom, the students being rotated so that each will learn the duties of all the functions concerned in an astrolabe observation. One or two night observations are made with astrolabe and results computed. The reason for giving the student the course in field astronomy is to acquaint him with some of the methods used and impress him with some of the problems encountered in azimuth and position determination, and to increase his knowledge of the entire sequence of map preparation.

WANTED—TRAINING—IN PHOTOGRAMMETRY

G. C. Tewinkel, U. S. Coast and Geodetic Survey

These remarks deal with the background of training this organization desires of its new employees of college graduate level working in the Division of Photogrammetry. The present situation is not an ideal one since many of the employees were wholly unfamiliar with mapping with photographs when they began working with the Division. And due to the lack of prospective professional employees, positions are being filled with sub-professionals whose special training is certainly adequate but whose visions are apt to be limited somewhat by the lack of a broad fundamental engineering training. Moreover, the civil engineer is frequently less interested and less prepared for work in photogrammetry than are the forester, geologist, mathematician, and physicist. The civil engineer is usually better prepared for work in bridge design and sewage disposal than in surveying and mapping. This is due partly to the comparative small size of the field of mapping and partly to the lack of information of the instructors as to the true state of affairs.

The reader is perhaps acquainted with the course in photogrammetry offered at Syracuse University. This school is mentioned because it furnishes the only basis of comparison with which I am familiar. It is felt that the undergraduate training furnishes the student with sufficient theoretical knowledge but with inadequate conceptions and skills in the operation of stereophotogrammetric instruments, in the art of making radial plots, and in the relative importance of the different phases and methods of map making. The graduate student does not appear to be much better equipped than the undergraduate. Hence, it seems than it is necessary for a student to devote even more time to the study of photogrammetry than is offered at Syracuse.

In my opinion, the college should stress both the fundamental theories and the operation of photogrammetric instruments, preferably the multiplex. The student should be able to visualize the deformations of the stereoscopic model due to the several states of improper relative orientation. I do not think the student should be proficient in multiplex operation, but he should be so thoroughly familiar with it that he is cognizant of his lack of training. The college trained photogrammetrist should be well informed of the principles and procedures of radial plotting because that method is perhaps the most widely used for making maps from photographs. He should understand the geometry of the aerial photograph with sufficient clarity so that he cannot make glaring mistakes and so that he knows the nature of the errors embodied in the system and the means for correcting and compensating for those errors. He should be informed as to the degree of precision that can be and is being obtained by graphic methods utilizing very simple procedures and instruments together with meticulous care in drafting.

It is not a practice of this organization to use only college graduates as stereoscopic instrument operators. Yet it creates organizational strength to have a few operators with college training, and also for all other professional men to be thoroughly familiar with the operation and limitations of the instruments. It is quite probable that most instrument operators should be sub-professional—should be purely skilled operators whose training has been highly specialized and limited. The training of these men is not a proper function of a university but of a training school or on-the-job training.

First, men are needed who have a good general knowledge of photogrammetry and allied surveying subjects, and, second, trained instrument operators are needed. At present neither is available. We find it necessary to train or partly train all our men—even the college graduates—both in field work and office work before they are sufficiently familiar with the procedures to be of adequate usefulness.

A course in theoretical photogrammetry is conducted periodically for groups of our employees on office time. The treatment of the mathematics is made to fit the background of the particular group being taught since all are not college graduates. The course consists of 24 hours of lecture time with numerical problems for the student to solve, and the requirement that the student keep a good, neat notebook. The student receives the practical side of his training while at work. The course includes simple geometric optics, the scale relationships of the vertical photograph, relief displacement, the principles of radial plotting, parallax and elevations, the human eye and stereoscopy, the geometry of the tilted photograph, simple analytic problems involving tilt, three methods for tilt determination, the theory of rectification, the oblique photograph, and stereoscopic plotting instruments. The purpose of the course is to explain to the photogrammetrist the fundamental reasons underlying his activities, to give him a well-founded basis for understanding the entire field of photogrammetry, to impress on him that the practice and theory of photogrammetry is far from exploited, and to encourage clear thinking with respect to the many practical problems of the science.

There is a regular program for transferring a few office men to field operations three to six months during the summers. Multiplex operators receive at least six months of non-productive training, and other instrument operators receive somewhat less. New employees are usually placed first in sections where they may receive training in the office techniques such as the manipulation of the drafting pen in map compilation, in the making of radial plots, etc.

There will probably always be a need for some sort of office training program in photogrammetry because the bulk of the work can be performed economically by non-professional workers of high school graduate level. Also, the science utilizes a number of comparatively simple principles and procedures that are little known outside the mapping field. The well informed engineering graduate is the logical person to conduct such a training program. In many instances his only source of photogrammetric knowledge has been his own office. His viewpoint is thus limited and his ability to teach the subject is curtailed.

It would indeed be helpful if the graduate photogrammetrist could enter duty prepared to go to work. Perhaps that is too much to expect since the graduate civil engineer is proficient neither as a draftsman nor as a transitman. It would even be an improvement over the present situation if each civil engineer had just six semester hours of wise instruction in practical photogrammetry. It is indeed a depressing situation when one visualizes the relatively limited number of positions available in the field of photogrammetry together with the high cost of instruments for the colleges. There might seem to be a practical limit on the number of colleges offering specialized training in the subject. But when one considers the facts that no large mapping program is undertaken today without considering the use of aerial photographs, and that the army with the best maps has always been victorious, then there seems to be little excuse for not including about six semester hours of photogrammetry in every civil engineering curriculum.

Gerald FitzGerald, Chief, Topographic Branch, U. S. Geological Survey

With regard to the committee's questionnaire, the following discussion is submitted as representing the consensus of several members of the Topographic Branch of the Geological Survey.

The subject of photogrammetric education can be broadly divided into two sections; (1) that which concerns persons who will use the results of photogrammetric surveys and, (2) that which concerns the photogrammetrists who will actually conduct the surveys. Our opinion is that a general course in photogrammetry, briefly touching upon all practical methods of compilation and stressing the accuracy of final results as well as their limitations, should be given to both of the above groups. This course should include only enough theory to satisfactorily explain the operating principles of the various processes and equipment. Its length should not be less than three semester hours and should consist of two 1-hour lectures and one 3-hour laboratory period per week for 15 weeks. The course content could well be planned around the items suggested by R. E. Ask in the chapter on "Training and Education" in the *Manual of Photogrammetry* (see *Manual*, page 756—suggested course outline.)

In addition to the general introductory course, an advanced photogrammetry course should be available in all engineering schools as an elective for civil engineering students who desire more information on the subject. It should be given preferably in the junior or senior year and should consist of at least three semester hours of work. About half of this course should be devoted to a study of fundamental mathematical principles such as:

(1) Coordinate relationship (X, Y, Z) between ground and photograph.
(2) Orientation of photograph with reference to coordinate system.
(3) The parallax equation and its applications.
(4) Theory of errors as applied to photogrammetric measurements.

The remaining half of the course should consider the application of these principles to various practical compilation methods and instruments.

The possibility of granting a Bachelor of Science degree in photogrammetry has often been suggested. Such a degree would no doubt benefit the profession, but would be very difficult to put in operation due to the relatively few students it would attract. A program of this nature might be possible if all advanced photogrammetric education were centered in one institution which had a substantial endowment specifically set up for that purpose. Furthermore, the organization of facilities for granting a Bachelor's degree would entail tremendous effort since it would be necessary to schedule between 15 and 20 different photogrammetric courses totaling about 60 semester hours (this being the average college requirement for a major in any subject).

In view of the difficulty involved in setting up a Bachelor's degree in photogrammetry at this time, we would suggest that considerable attention be given the following alternative—namely, that several of the major engineering schools establish sufficient elective courses in photogrammetry and allied subjects so that interested Civil Engineering students can take all of their electives (possibly 15 hours) in this field. A listing of suggested courses follows:

A. Introduction to Photogrammetry—3 semester hours (required of all C. E. Students—previously described above).
B. Advanced Photogrammetry—3 semester hours (elective course—previously described above).
C. Photography (elective)—2 semester hours.
D. Photogrammetric Optics (elective)—2 semester hours.
E. Cartography (elective)—3 semester hours.
F. Elementary Geodesy (elective)—3 semester hours.
G. Special Photogrammetric Problems (elective)—3 semester hours.

We believe that most photogrammetric organizations would benefit more in the long run if their new junior engineers had a broad general knowledge of photogrammetry rather than a specific operational knowledge of one particular instrument. Furthermore, even under an expanded educational program, training on any specific instrument would be difficult to obtain for the following reasons:

(1) Equipment not available.
(2) Time not available.
(3) The student cannot predict what type of instrument his future employer may use.

A broad general knowledge of photogrammetry will enable a new employee to tackle many problems in various branches of the science.

Another idea which merits study is the possibility of a few schools offering a one-month highly concentrated refresher course in photogrammetry for practicing photogrammetrists, engineers, and geologists. Such a program would benefit the greatest number of persons if it were given in about three schools located respectively in the eastern, central and western regions of the United States. Similar courses apparently were quite popular in Europe—for instance, the text of Van Gruber's book "Photogrammetry" is made up chiefly of lectures delivered in courses of about three weeks' duration. Also short courses have been given over a period of years in Switzerland.*

* Editor's Note. Short courses will be resumed by the Swiss Federal Institute of Technology in the spring of 1948. See announcement, p. 479.

II. Educational Institutions

OUTLINE OF COURSES IN PHOTOGRAMMETRY GIVEN AT RENSSELAER POLYTECHNIC INSTITUTE

H. O. Sharp, Acting Head, Department of Civil Engineering

There are three courses in photogrammetry now given at Rensselaer in the post war civil engineering curriculum:

1. The elementary phases of photogrammetry are given as part of a combined course with advanced surveying. All civil engineering students take this course and it is designed to meet the needs of two groups of students: those who will take the elective in advanced photogrammetry and those who will take other electives.

2. An elementary course in photogrammetry for Navy (Civil Engineer Corps) student officers. This course is much the same as No. 1.

3. Advanced photogrammetry is given as part of the course in geodesy and photogrammetry.

The larger group of civil engineering students belong to the group which takes only the first course. Not specializing, their lasting impression will be that photogrammetry is a phase of surveying,—an important, rapidly growing phase, to be sure, but still only a phase. In the sense that "a little knowledge is a dangerous thing," it is more important for these students to get the proper perspective than for those who will specialize. A man who, having been exposed to the subject, tries to make use of it beyond its limitations or fails to use it where it would have been economical, might better never have taken the subject. A man with proper appreciation will know how far he can go with photogrammetry and when to call in an expert.

The students themselves make prints from the negatives in the dark room which is part of the facilities. The prints are used for reconnaissance on the surveys; and again, the control systems of the surveys are laid out with an eye toward later use in the photogrammetry laboratory. Thus the student as a surveyor is made photograph-conscious, and the student as a photogrammetrist becomes familiar with the field work at first hand. The student has a greater incentive to do one part of his work well if he knows that its quality will affect the ease and quality of another part of his own work.

For lack of equipment, the theory part of the course naturally has greater scope than the laboratory, particularly in view of the large classes currently in attendance. The theory begins with the study of lenses, cameras, films and papers, accompanied by dark room work. Planning of an aerial survey is made next, with each student making a flight map of his own over a given area. Next, the principles of perspective and iconometry are reviewed and applied to graphical plotting from terrestrial photographs.

Stereoscopes, stereoscopic parallax and the stereocomparator are next. To reduce to a minimum the number of students who are unable to see stereoscopically, each student's first introduction to the stereoscope is with the stereoscope all set up previously, with proper spacing, orientation and favorable lighting.

Of the many plotting instruments which the student learns about in the theory, only the stereocomparagraph and contour finder is available to him in the laboratory. These he uses to obtain differences in elevation in a practical problem for determining the lengths and bearings of a parcel of land visible on his prints, as well as the plotting of contours.

The student uses the ground control obtained during the summer surveys for assembling his photographs, using variations of the radial line method of plotting a planimetric map. He is able to compare the map thus made with his ground survey map of the same area. He also makes a map from an oblique aerial photograph.

Most of the analytical work is confined to the advanced photogrammetry, although a small amount is included in the elementary courses.

It will be seen from the remarks just made, that Rensselaer does not offer a special course in photogrammetry leading to a degree nor does it attempt to make experienced operators for any of the large stereoscopic plotting instruments.

For instance, it would be quite impossible to equip a laboratory with enough multiplex and stereoplanigraph equipment to train operators even though enough time were allowed for the training. It is the opinion of those on the staff at Rensselaer that this training must be given through cooperative programs with agencies who have equipment of this kind. It is here that the American Society of Photogrammetry can be of considerable help to those young men who designate a desire to make photogrammetry a profession. Technical schools can cover the various theories supplemented with some practical work but it is too costly to equip themselves with large amounts of expensive equipment. Our school has several cooperative courses with large industrial companies and it is possible to expand this to the field of photogrammetry with the cooperation of the members of the Society.

It is somewhat doubtful as to the number of photogrammetrists that can find suitable employment if trained as specialists. The field is somewhat limited and probably does not warrant the training of large numbers of men who have no other field to fall back on in times of inactivity in the field of photogrammetry. For this reason, the staff at Rensselaer has not recommended a special division of civil engineering devoted only to the problems of photogrammetrists. It is quite likely that a few men of ability can make a mark in this field but it is probable that the average run of graduates would be limited in their progress.

PHOTOGRAMMETRY AT THE UNIVERSITY OF TENNESSEE

H. B. Aikin, Assistant Professor of Civil Engineering

This is a brief summary of the work we do in photogrammetry. As you will see we do not, at the present time, devote much time to the subject and can cover only some of the more fundamental ideas of the subject.

Elements of Photogrammetry

Approximately 15 hours are devoted to this subject in a course which is called Advanced Surveying. This time is spent in lecture and recitation; no laboratory work is given at this time.

Outline of material covered

Definition of fundamental terms.

Terrestrial photogrammetry; the general principles involved.

The stereoscope, stereoscopic parallax, the three fundamental parallax equations.

Aerial photographs

Scale, changes of scale, overlap of pictures, number of pictures to cover an area, time interval between exposures.

Displacements: due to relief and to tilt; directions of.

Preparation of maps from aerial pictures

Methods involving the use of vertical pictures, or those assumed as vertical.
 Principle of radial intersection.
  Templates, slotted templates, mechanical triangulation equipment.
Transferring of detail from the pictures to the control which has been plotted; methods used.

Methods involving the use of stereoscopic plotting instruments

A brief consideration of the various types of equipment used for plotting topographic maps, based upon stereoscopic principles.

PHOTOGRAMMETRY AT THE INSTITUTE OF GEOGRAPHICAL EXPLORATION, HARVARD UNIVERSITY

Edward S. Wood, Jr., Instructor in Aerophotography and Aerosurveying

The Institute of Geographical Exploration, which was founded in 1931 by Dr. Hamilton Rice, offers instruction in cartography, field communications, and photogrammetry under the supervision of the Department of Geology and Geography of Harvard University. The Institute occupies a two-story building in Cambridge where classroom and laboratory facilities are available for each of the subjects offered.

The course in photogrammetry has been given continuously since 1932, except for one year during the war when the staff was away. The emphasis in the instruction has changed during this period to meet changing conditions. Originally much time was devoted to aerial photography with the T-3A camera and the production and use of the resulting composite pictures. Now the subject is presented with particular attention to the needs of the geologist and geographer, stress being placed on methods and equipment that are simple in operation and low in cost, since these are the tools ordinarily available. The course is open to both undergraduates and graduates concentrating in the scientific departments of the University.

Since many men majoring in geology feel that one semester is all the time they can spare from their chosen field, the material is so arranged that the first semester covers the fundamental photogrammetric principles that a geologist must know in order to utilize aerial photographs to the best advantage. In the second semester actual photographic processes, the more elaborate plotting instruments, and methods of obtaining the necessary ground control receive more consideration. When funds are available actual photographic operations are undertaken in areas of especial interest to various departments of the University.

The actual instruction consists of two hours of lectures and six hours of laboratory work per week. The lectures in the first semester cover such subjects as interpretation; cameras, lenses, and filters for aerial photography; planning the photographic mission; geometric characteristics of aerial photographs with special emphasis on the nature and relative magnitude of relief and tilt displacements so that the radial line assumption may be easily grasped and the students are prepared for radial line plotting and mosaic compilation. After an explanation of the various transfer devices, the theory of height determination by stereoscopic methods is considered with some time devoted to the sources of parallax errors in "vertical" photographs. The use of obliques is discussed and the Canadian grid system is described in detail. Having learned how tilt is found by use of the horizon on a high oblique, the students are then introduced to tilt determination on "vertical" photographs by scale check lines. A summary of grid systems and map projections completes the lecture portion of the semester's work.

In the laboratory the students obtain experience in interpretation, and lay an uncontrolled mosaic which is checked against the 1:31,680 Geological Survey sheet. Streamlining, ridge lining and logical contouring are performed with both mirror and lens stereoscopes; parallax measurements are made with the stereocomparagraph, and the tilt of a photograph is determined by scale check lines. A radial line plot is made with radial angulators and a planimetric map of the area is prepared using the sketchmaster, multiscope, etc., for the actual transfer of detail. Another planimetric map is made from a high oblique and both maps are checked with the appropriate Geological Survey sheet.

The second semester's lectures are devoted to the characteristics of photographic materials with special attention to speed, spectral sensitivity, resolution, graininess and the characteristic curves. Consideration is given to the effect of haze and the use of filters in aerial photography. Contouring unrectified pictures by means of the graph of equal sea level readings is stressed, since it seems particularly adapted to the needs of geologists. An account of the multiplex and Brock methods shows the methods that must be employed when accurate contours are essential. Two lectures are devoted to rectification so that the students should be able to compute the four quantities required for setting the rectifying printer. A discussion of trimetrogon mapping and the various methods of obtaining ground control is included in the second semester.

During this time the students devote the laboratory periods to contact printing, preparing a radial line plot for a controlled mosaic, calculating the ratios, making and laying the ratioed prints and assembling and copying the mosaic which is checked with the Geological Survey map. A rather hilly area is contoured with the stereocomparagraph using lines of equal sea level reading to reduce the errors due to tip and tilt. A profile taken from the student's map is compared with the profile as obtained from the Geological Survey map in order to furnish some idea of the accuracy to be expected when using unrectified pictures.

The Institute's K-3B camera is available when aerial work is undertaken and the students do their own processing with a Fairchild-Smith developing outfit.

It is felt that the combination of theoretical lectures together with actual practice in standard photogrammetric operations should enable the student to use either vertical or oblique photographs intelligently and expeditiously.

A research course is offered to qualified students who desire to do more advanced work. Those taking this course may either investigate some special phase of photogrammetry or the application of photogrammetry to some other field of endeavor such as highway location, regional planning, or regional geography.

PHOTOGRAMMETRY AT THE UNIVERSITY OF KANSAS

H. T. U. Smith, Associate Professor of Geology

At the University of Knasas, photogrammetry is taught in the department of geology, primarily to fill the needs of students planning to enter the profession of geology or of petroleum engineering. The basic course, Geology 216, *Photogrammetry and Photogeology*, is a one-semester course for three hours credit, open to seniors and graduate students. Approximately two-thirds of the course is devoted to photogrammetry, and one-third to photogeology. Photogrammetry is presented primarily as a working tool for the geologist who may need to prepare his own base maps. The following topics are covered: geometric properties of vertical and oblique photos; principles of stereoscopy; uncorrected methods of planimetric mapping from vertical photos; radial line planimetric mapping with both hand templets and mechanical templets; contouring on vertical photos; and preparation of planimetric maps from oblique photos by both rectification and trinagulation methods. The student acquires familiarity with the use of the following instruments: reflection and refraction types of stereoscopes; stereocomparagraph; vertical sketchmaster; universal sketchmaster; Kail radial-line plotter; mechanical templets; and rectoblique plotter. In addition, an aerial camera is available, although its use is not a required part of the course.

That part of the course dealing with photogeology comprises training in the interpretation of geologic features shown on aerial photos, and preparation of a geologic map from a set of vertical photos covering an area of about 70 square miles.

Research courses in which the methods of photogrammetry and photogeology are applied to particular areas are offered for graduate students, and may be taken in connection with the master's or doctor's thesis.

Plans are now being made for systematic advanced training in both mapping methods and photo interpretation. These plans include addition of the following equipment: vertical sketchmasters, templet slotter and other equipment for the slotted templet method; Mahan contour plotter, and Multiscope.

PHOTOGRAMMETRY AT COOPER UNION

John O. Eichler, Associate Professor of Civil Engineering

The need of an elementary course in photogrammetry, for the undergraduate student in civil engineering, was found desirable at The Cooper Union. As uses of photogrammetry have increased during the past years it became evident that the graduate civil engineering student going forth with no knowledge whatever of the subject would be handicapped should he meet with a problem in which the uses and principles of photogrammetry were involved. With this in mind, the course was designed, not to make trained photogrammetrists, but to give the students the fundamentals and principles of photogrammetry, in other words, the tools to start.

The maximum time that could be allowed for the course in photogrammetry was three hours in the senior year. This time was divided into one hour lecture and two hours laboratory. Working on the present 16 week semester, a total of 48 hours of instruction results.

The present outline of lectures is as follows:

1. History and Uses of Photogrammetry.
2. Terrestrial Photogrammetry.
3. Aerial Camera, Uses, Parts, etc.
4. Basic Definitions, Basic Scale formula.
5. Relationship between ground coordinates and image coordinates on a vertical photograph. Topographic Relief.
6. The Stereoscope, Parallax.
7. Measuring Stereoscope, Stereocomparagraph, Contour Finder.

8, 9. Tilted Photographs, Definitions and Scale Data.

10, 11. Problems, Scale, Finding lengths of lines, determining elevations and other applications of the basic formulas.

12. Mosaics.
13. Radial Plotting.
14. Multiplex Projector, Tri-Metrogon Plotting.
15. High Oblique Photographs.

The laboratory sections are divided as follows:

1. Problems in flight planning.
2. Use of simple stereoscope, orientation.
3, 4. Measuring stereoscopes, orientation, calibration of the micrometer screw.
5. Calculating Air-Base, Flying Heights from parallax measurements.
6. Elevations of any point.
7, 8. Making small contour map.
9, 10, 11. Making Mosaic.
12, 13. Radial Line Plotting.
14. Use of Dark Room

Time has been allowed for the giving of quizzes during the semester. A short quiz is planned during one lecture period, mainly on definitions and two longer quizzes during the laboratory periods. A final examination is given at the end of the semester. The number of quizzes eliminates the necessity of recitation periods.

The foregoing listed laboratory exercises must be varied at times, when large class enrollment is experienced, due to insufficient numbers of certain equipment.

The subject of optics has not been included in this general outline, because of the shortness of time and, further, the basic principles have been developed in their preceding work under the Department of Physics. Only one lecture period is devoted to terrestrial photogrammetry because of time limitations, and the belief that its uses are more limited. A separate course for graduate work is recommended.

The use of the dark room as the last laboratory period, as outlined above, may be open to discussion, but at Cooper Union an adequately equipped dark room is available. This enables the student to develop, print and enlarge a series of aerial photographs. The problems of enlarging aerial photographs and the resulting limitations of the prints are shown at this time.

At the present time we have two Fairchild stereocomparagraphs twelve small stereoscopes, a calculating machine, and two drafting tables with Universal drafting machines attached.

In the near future we intend to purchase two Abrams contour finders, two mirror stereoscopes, and a set of metal templates.

Last year we used, *Elements of Photogrammetry*, by G. D. Whitmore. The text was supplemented by assignments from *Elements of Aerial Photogrammetry* by Prof. Earl Church and the *Manual of Photogrammetry*. A set of aerial photographs of the Cooper Union Green Engineering Camp situated at Ringwood, Passaic Co., N. J., are used for many of our calculations. Ground control is being extended so that the area will be completely covered. A selection of photographs of other areas have been purchased from Fairchild Aerial Surveys, Inc.

The *Manual* rewritten as a text is recommended. The present *Manual* being written in the style of a reference book for photogrammetrists is not suitable as a textbook for students in an elementary course in photogrammetry. The portion devoted to laboratory work could be revised in order to facilitate teaching this phase of the subject.

The Society can assist by having more of this type of discussion. All schools seem to have courses that vary considerably and a more uniform elementary course is recommended. A meeting, sponsored by the Society, of all teachers of photogrammetry would be helpful. The meeting could include talks by outstanding men in the field of photogrammetry and round table discussions on individual problems. More could be accomplished at one meeting than in a dozen articles.

PHOTOGRAMMETRY AT WEST VIRGINIA UNIVERSITY

Wilfred H. Baker, Associate Professor, Department of Civil Engineering

The course in photogrammetry at West Virginia University is elected by the civil engineering students in their senior year. The course carries two semester hours credit which, schedules permitting, is equally divided between lecture and laboratory. Thus it may be appreciated that there is time only for basic principles and elementary applications. We have acquired, quite gradually, some of the less expensive pieces of equipment until more recently when considerable has been obtained through war surplus disposal.

A list of the topics covered in the lecture part of the course includes the following:

The various types of cameras, their characteristics, the uses for which each is especially adapted, their construction, parts, focal length, and interior orientation.

The planning of a flight for an aerial photographic project, including such considerations as time required, film, exposure intervals, placement of flight strips, flight maps, and total cost.

The geometry of the photograph, principal distance, principal point, isocenter, displacements due to tilt and relief.

The principle of the stereoscope and the basic parallax equation; its use in determining elevations and contours.

Graphical and analytical methods for the determination of tilt.

Instruments and methods for plotting planimetric and topographic maps. These include the various methods of radial line control; the stereocomparagraph and contour finder; the multiplex projector and the aerocartograph.

Mosaics, their properties, uses, and techniques of making.

Grid methods of mapping from obliques. In this connection, considerable material has been obtained from the Canadian government illustrating the method in use there.

The first laboratory exercise usually consists of a field trip for the purpose of interpretation of photographs and identification of points, and comparing ground features with their photographic images. For photographs we have those taken for the Agricultural Adjustment Administration covering the area around Morgantown as well as an area around Terra Alta, the location of our summer surveying camp. Practise in the use of field stereoscopes is obtained in this exercise.

The main laboratory problem is the construction of a planimetric map by the radial line control method. Each student or pair of students (when the class is large) is issued a strip of about six photographs. A radial line plot is made, using either the tracing cloth or the celluloid templet method of extending the control network. One handicap here is a lack of suitable ground control, since we have no time for running any in the field. What we commonly do is to make a floating plot at the approximate scale of the photographs and later determine the scale by comparison of an over-all distance on the plot with that of the U. S. G. S. topographic sheet. This deprives the student of the questionable pleasure of trying to fit the radial plot to ground control and is perhaps misleading to that extent. Details are transferred either by direct tracing from the photographs of by means of the sketchmaster.

As a continuation of this problem, contours are added using either the stereocomparagraph or contour finder. Vertical control is taken from the U. S. G. S. topographic sheets. This complete problem results in a topographic map covering some fifteen square miles. Although time usually does not allow the construction of a complete contour map of the entire area, the student does get practice in stereoscopic viewing and the use of the floating mark. The radial line problem together with the stereocomparagraph presents a fairly complete solution of the problem of topographic mapping, which, because of its relative simplicity, is perhaps the more satisfactory for the presentation of basic principles.

Other laboratory problems may include the graphical determination of tilt by the upright planes or pyramid method; an analytical solution of the tilt problem; and a flight planning problem; these being assigned as time and suitability allow.

Photographic equipment includes two aerial cameras, a Fairchild F-56 and a Fairchild F-11, both obtained from war surplus equipment; a contact printer, and dark room equipment for the making of contact prints.

At the present time we are fairly well equipped for the course we are giving. It is possible that, with increased enrollments, more advanced work may be offered in which case one or more or the costlier plotting instruments will be desirable, as well as more equipment for the photographic dark room. One lack is that of a suitable well written text book which satisfactorily covers the field. While we find several on the market, it is still difficult to get complete coverage in the manner that is felt desirable for an elementary course.

PHOTOGRAMMETRY AT SYRACUSE UNIVERSITY

A. O. Quinn, Assistant Professor of Photogrammetry

Photography and photogrammetry are old and familiar words at Syracuse. A course in basic photography was introduced in 1902. This course, with the necessary revisions required to keep it up to date, is still given in the College of Applied Science.

In 1929, Syracuse received a grant from the Daniel Guggenheim Fund for Aeronautics to introduce work in aerial and terrestrial photogrammetry and procure equipment for extensive laboratory work. With the money from this Guggenheim Fund, and the assistance of an advisory committee, consisting of outstanding men in the photogrammetric field, the University has acquired considerable photogrammetric equipment. This material includes the multiplex aeroprojector, diapositive printer, stereocomparator, photogoniometer, phototheodolite, comparator, Fairchild stereocomparagraph, Abrams contour finder, several aerial cameras, photographic dark room, rectifying camera, small stereoscopes, etc.

Through the efforts of Professor Earl Church, courses have been developed in both aerial and terrestrial photogrammetry for graduate and under graduate students. Primary consideration has been given to familiarizing the student with the theoretical and analytical phases of photogrammetry, with the feeling that the details and the techniques of individual employers can best be grasped by a student who is thoroughly grounded in fundamentals. This does not mean that practical problems and methods are not discussed and developed by the students in laboratory exercises.

Since photogrammetry is a most valuable tool in the hands of the civil engineer, the department has worked in close cooperation with the Department of Civil Engineering. All civil enginneering students are required to take a course in Elementary Photogrammetry, and an option, "Higher Surveying and Photogrammetry," is available to those interested in that phase of civil engineering. Students taking the option are eligible to obtain a Bachelor's degree in Civil Engineering. All the courses given by the Department are available to any student of the university possessing the necessary prerequisites and a large number of students from the New York State College of Forestry are enrolled. Students in geography and geology are particularly interested in photogrammetry to assist them in the solution of their problems.

A Master's degree may be obtained by completing required course work and a thesis dealing with a problem in photogrammetry. This work usually requires one year of residence work.

The following sequence of courses in the Department of Photogrammetry has been set up for students electing the option in "Higher Surveying and Photogrammetry": Elementary Photogrammetry (required for all civil engineering students), Photographic Interpretation, Geometric Optics, Terrestrial Photogrammetry, Advanced Photogrammetry, Stereoscopic Mapping Instruments, Geodesy and Astronomy and Least Squares.

The course in Elementary Photogrammetry is designed to give the student a working knowledge of the fundamental principles of the subject together with an appreciation of the problems confronting the photogrammetrist. The work includes: The history and development of photogrammetry, aerial cameras, principles of stereoscopy and stereoscopic instruments, scale and tilt determinations, mosaics, radial line plotting, oblique photographs, and a brief exposure to the multiplex aeroprojector. The course consists of two one-hour lectures and one three-hour laboratory per week. In the laboratory the student works problems in flight line planning; uses the Fairchild stereocomparagraph and Abrams contour finder; analyzes aerial photographs for scale and tilt; constructs a radial line plot using the Abrams mechanical triangulator (Lazy Daisy); compiles a map from the radial plot using the Saltzman projector; and prepares a mosaic. Field inspections are made in adjacent areas covered by aerial photographs, and the problems of photo control and photographic interpretation are discussed. The brief time spent with the multiplex is designed to acquaint the student with the stereoscopic principles involved and the potentialities of the equipment for topographic mapping work. Since most of the calculations used in photogrammetry are greatly simplified by the use of a calculating machine, each member of the group is required to pass an examination in the operation of a calculating machine. The text book that is used is Professor Earl Church's *Elements of Aerial Photogrammetry.*

The course in Photographic Interpretation has been introduced because of the wide spread interest in the use and interpretation of aerial photographs. The course is largely devoted to office examination and interpretation of photographs and the field investigation of actual ground conditions. The correlation between topographic maps, aerial photographs, and actual ground conditions is demonstrated. Elementary mapping, construction of terrain model and dark room practice are included in the course.

Since the photogrammetrist depends upon optical instruments in one form or another, to complete his work, a fundamental course in Geometric Optics, given by the Department of Physics, has been included in the curriculum. Special applications of the theory of lenses to cameras and surveying instruments are made, and the student becomes familiar with the optical bench and the general problems encountered in the design and construction of optical equipment.

Terrestrial Photogrammetry includes the problems and principles of photogrammetry as applied to the use of the photo-theodolite for mapping work. The students survey an area using terrestrial photographs and the Stereocomparator, checking the results by means of the usual surveying methods. Additional work in photographic dark room technique is given, and all processing and printing of photographic plates is done by the students.

In the two courses, Advanced Photogrammetry and Stereoscopic Mapping Instruments, spatial resection, space orientation, and space intersections are studied and computations are made from the comparator, stereocomparator, and photogoniometer measurements on aerial photographs, using the various analytical methods developed by Professor Church and other photogrammetrists

The mathematical analysis of the problems in spatial resection and space orientation form the basis for further computations in the analytical expansion of horizontal and vertical control. Many of the methods used by the Department have been published by the University in the form of Bulletins on Aerial Photogrammetry.

Further study is devoted to the orientation and actual operation of the multiplex aeroprojector to produce topographic maps, and other types of stereophotogrammetric equipment are investigated. In order to give the student a well rounded knowledge of the entire mapping problem from the first plans for aerial photography and ground control to the delivery of the completed printed map, he makes a preliminary edit and field check of the topographic maps prepared by the multiplex, does the topographic drafting for finishing the map and completes a final edit and instructions for reproducing the map. Methods of reproduction are discussed and copy and rectifying cameras, sketchmasters, etc., are used in the laboratory. The students are kept up to date by reviewing new methods, equipment, etc., as published in PHOTOGRAMMETRIC ENGINEERING. These courses form the basis for further individual investigations and study offered in strictly graduate courses.

The surveying part of the curriculum is given at the Summer Surveying Camp (six weeks), and courses in Geodesy, Astronomy and Least Squares. The Summer Camp program includes considerable work in the ground methods and accuracy used in obtaining photo control. Practice work includes traverses, leveling, triangulation, three-point observations, signal building, and the use of aerial photographs.

The future of photogrammetry as an accurate economical and rapid means of mapping large areas is exceedingly promising. There are literally thousands of ways in which aerial photographs can be of great value to both large and small business, and the many service men and women who have seen the important part that photographs played during the war are anxious to attack these fascinating problems. Because of the new importance of electronics to photogrammetry, the Electrical Engineering Department at Syracuse University is preparing to give special related work and the use of stereoscopic mapping equipment in other fields of science is certainly a coming possibility. The photogrammetrist is young in his profession; his sphere for work is ever enlarging, and he is assured of an important place as a man of science.

TEACHING PHOTOGRAMMETRY TO FORESTRY STUDENTS

Robert N. Colwell, School of Forestry, University of California

Before an instructor can consider himself qualified to present definite recommendations regarding a course, he should himself have taught the course several times, perhaps modifying his methods and subject matter with each successive class of students. From this standpoint the writer is not qualified to write on the subject indicated, as he has just recently finished teaching his first course in photogrammetry to forestry students. However, this does not deter him from accepting the invitation to join with other contributors in "a frank discussion of teaching problems and the publication of recommendations" in the hope that many mutually beneficial ideas will result.

In deciding upon the appropriate subject matter to be included in a photogrammetry course for forestry students, the basic consideration seemed to be "what photogrammetric methods will be of primary value to the majority of forestry students once they get out on the job?" This (and budgetary considerations) eliminated any further consideration of offering detailed instruction in the use of such precise photogrammetric instruments as will rarely, if ever, be available to the forester. For example, it appeared that the "radial line plot" method of planimetric mapping, requiring only some aerial photos, a simple lens stereoscope, a piece of cellulose acetate, and a few inexpensive drawing instruments would be useful and workable in nearly any forestry field job and would give a mapping accuracy commensurate with that required for many forestry purposes.

It seemed desirable in teaching this course to use aerial photographs of a forested area which the student could visit on the ground, and accordingly the area chosen was the University of California Forestry Summer Camp area in which each forestry student works for one summer. The wide variety of forest sites and types in this area had been a factor favoring its selection for the location of Summer Camp; it was also a factor favoring its selection for photo mapping problems, particularly for the stratification of forest types in accordance with Forest Service procedure.

Planimetric mapping and stratification of vegetation types from these aerial photographs, therefore, emerged as two important phases of the course.

A third phase of the instruction was that of contouring the same area on which phases 1 and 2 had been performed, thus permitting the student to prepare, for an area visited by him on the ground, a topographic map on which forest type boundaries might be superimposed. Further integration of the course was effected by giving, for the same area as above, preliminary problems in flight line planning and photo indexing.

From recent standard Forest Service vertical photography, scale 1:20,000, each student was issued 14 aerial photos of the Forestry Summer Camp area. These photos constituted portions of 3 overlapping flight lines, thus necessitating a lateral tie-in when mapping.

Since it was apparent from the first that most of the students would not be able to map the entire area in the allotted time (15 hours in the laboratory, plus 6 to 12 hours outside of class) mapping of all of the central strip and the resecting in of at least one photograph of an adjacent strip was required, thus keeping the class together during the start of the exercise and assuring that a common area would be mapped by all students. During the allotted time most students prepared a planimetric map for only the central 20 to 30 square miles covered by the photos. The more accurate of these planimetric maps, (those prepared by about 1/4 of the students in the class), showed no photo control point more than about 300 feet from its true plan position. This is believed to compare quite favorably as to accuracy with a rough planimetric map of the same area which the students might have prepared in 60 to 75 man-days by compass and pacing or by running a ridge and stream meander with transit and stadia. It should be emphasized, however, that such direct comparisons are very difficult to make. Without question, the major vegetation type boundaries for this area were much more readily and accurately delineated on the photos than they could have been on the ground.

Eight hours of laboratory time were allowed for the stratification of vegetation types on a minimum area of about 10 square miles, and 6 hours were allowed for the "contouring" of a minimum area of about 5 square miles. The latter was done with an ordinary lens type stereoscope, with the aid of spot elevations, and the contours were drawn directly on the photographs.

For each phase of the work the faster students were kept profitably employed in mapping a more extensive portion of the area covered by the 14 photos than the minimum indicated above. Portions of the area which no student had mapped in the allotted time were used for quiz purposes and gave a good indication of the student's mastery of the work.

All examinations were of the "open book" type and were based on aerial photographs to the maximum extent possible in an effort to measure the student's working ability rather than his ability to memorize abstract photogrammetric definitions or formulae. It was felt that he would normally have access to the latter through lecture notes or text books when doing forestry work involving photogrammetry. One third of the course grade was based on laboratory work and two-thirds on examinations.

The hours of instruction for the course were two 1-hour lectures and one 3-hour laboratory period per week for 15 weeks. Three units credit were given for successful completion of the course. The class consisted of 4 graduate students, 19 seniors, and 4 juniors, all with a major in forestry. This proved to be about the maximum size of class to which one instructor could give the proper individual attention during laboratory periods, even when minimizing the individual instruction necessary by keeping all students engaged in the same phase of the problem whenever practicable.

In addition to the laboratory exercises which have been described, one 3-hour laboratory period was devoted to each of the following: (1) stereoscopy and height measurement; (2) a trip to the Surveys and Maps Section of the U. S. Forest Service Regional Office at which time the class observed photogrammetric methods currently used by the Forest Service; (3) a problem in planimetric mapping from an oblique aerial photograph of an area of relatively flat terrain, using the Canadian Grid method; and (4) a lecture-demonstration on the use made of aerial photographs by personnel conducting the current nation-wide forest survey. Also during the appropriate laboratory period each student was given an opportunity to operate a stereocomparagraph, KEK plotter, pantograph, and Kail radial planimetric plotter.

Lectures were geared to the laboratory work insofar as possible, in order to allow maximum use of each laboratory period for the working of problems. This still left considerable time throughout the course for lectures on such topics as (1) the geometry of aerial photographs and the nature of distortions due to relief and tilt; (2) the taking and processing of aerial photography, including demonstrations of a typical aerial camera, intervalometer, and other photographic equipment; (3) the effect of film, filter, and scale on the usefulness of aerial photographs for forestry purposes; (4) the laying of a controlled photomosaic; (5) the construction of a terrain model; (6) the measurement on aerial photos of volumes of forest stands and of individual trees; and (7) the use of aerial photos by (a) the Soil Conservation Service, (b) the Production and Marketing Administration, (c) the U. S. Geological Survey, (d) the Armed Forces, and (e) foreign countries.

One major problem which developed in connection with the presentation of the course was that of assigning material for outside reading. No single textbook contained a full treatment of the subjects studied in class. The *Manual of Photogrammetry* would most nearly have filled our needs, despite its more detailed and complex mathematical treatment of some of the subjects than was considered appropriate in this course, but it was outside the price range of a required textbook.

Accordingly, a less expensive text was used which had to be supplemented with a great deal of mimeographed information. Most of the outside reading assignments were made optional rather than required because of the limited number of library copies available. A student carrying a full study load rarely, if ever, gets around to doing "optional" study. Although many optional reading assignments were given in the *Manual of Photogrammetry* throughout the semester, with a strong recommendation that they be read, the book was checked out of the library only 7 times during the entire semester. There were, of course, unrecorded instances in which the book was studied in the library, but these were assuredly few.

This statement is not intended as an indictment on the class, since the tendency to perform only required study seems quite universal among students. For example, during World War II, when for a time the writer had charge of photo intelligence training for the U. S. Navy he observed the same tendency among officer students despite the fact that most of them were sincerely eager to learn the subject. Even spectacular demonstration material fresh from the combat area, when placed in the classroom frequently went unheeded despite an oral explanation as to its nature and importance and a strong recommendation that it be examined on completion of the required problem.

All of this is by way of emphasizing the great need for a cheaply priced text on the use of aerial photographs for forestry purposes to be used in conjunction with the course so that required reading may be assigned. It is understood that Professor Stephen H. Spurr of Harvard Forest is currently preparing a text for early publication on the use of aerial photographs in forestry. Such a text should materially assist the teaching of any forestry course in photogrammetry.

A course in photogrammetry for forestry students is at present offered in only a very few universities. It is believed, however, that the time is not far distant when most schools of forestry will make such a course prerequisite to graduation. That this should be done was the opinion volunteered by several students upon completion of the course which has just been described.

The invitation to write this article included a request for suggestions as to ways in which the American Society of Photogrammetry might assist the teachers of photogrammetry. In response to this request it is suggested that consideration be given to the desirability of the Society's sponsoring a series of texts which might be known as the American Photogrammetry Series, each text of the series being written on some special field of photogrammetric application such as geology, forestry, engineering, city planning, etc. Editing of these texts by a committee of the Society would assure the use of standard terminology throughout the series.

In the Introduction to the *Manual of Photogrammetry* it is stated that the *Manual* was written "with the idea in mind that it will serve as a text for all those interested in aerial photogrammetry," and with the hope that subsequent editions of the *Manual* would provide a "complete and up to date presentation of the entire field." As the uses of photogrammetry multiply and courses in photogrammetry become of a more specialized nature, the accomplishment of these aims in a single volume would seem to be not only undesirable, but a manifest impossibility. The need in any specific course in photogrammetry is for a smaller, less expensive text containing a more extensive treatment of the special phases of photogrammetry which are being considered in the course. Such a series of texts would serve to place before all students of photogrammetry evidence of a very worthwhile contribution to the field by the American Society of Photogrammetry.

FORESTRY ASPECTS OF PHOTOGRAMMETRY AT THE HARVARD FOREST

Stephen H. Spurr, Harvard University

The Harvard Forest, located some 70 miles west of Cambridge in Petersham, Massachusetts, is a part of Harvard University offering opportunities for advanced study and research in forestry and related fields. As a unit in the Institute of Research in Experimental and Applied Botany and the Department of Biology, emphasis is placed upon silviculture and related fields dealing with the biological basis of forest management, but various aspects of forest economics and forest mensuration are also covered.

Graduate Instruction

The Harvard Forest does not offer instruction in photogrammetry as such. Courses in this field are given by the Institute of Geographical Exploration, Harvard University, Cambridge, Massachusetts. At Petersham, instruction is offered only on a graduate level in the use of aerial photographs in forestry.

Students in the Graduate School of Arts and Sciences may study at the Harvard Forest toward the degrees of Master in Forestry, Master of Arts, and Doctor of Philosophy. The program of each student is tailored to meet his individual needs and frequently includes work in other parts of the University. For instance, it is entirely possible for a student to spend one semester in Cambridge studying photogrammetry and the second in Petersham working on forestry applications of photogrammetry.

Instruction in Petersham during the academic year is based upon the case method. Each student is assigned a series of cases or problems which are chosen to round out his education and to give him desired specialized training. Each problem is first discussed by the staff and students in conference. Then the student undertakes library work, field investigations, and analysis of data required by the problem, discussing his progress with his instructors as the need arises. A final report is prepared in writing which is taken up at a final seminar attended by the staff and students.

Students interested in the application of aerial photographs in forestry will ordinarily give special attention to three aspects of the field: the use of photographs in forest stand mapping, in estimating timber volumes, and in controlling woods operations. All of these phases involve a knowledge of photogrammetry as well as of forestry. The student must make considerable use of radial line triangulation, stereoscopes, and simple transfer devices such as the multiscope, camera lucida, reflecting projector, and radial planimetric plotter.

The nature of the cases assigned to graduate students is varied to meet the needs of the individual and to accommodate recent advances in forestry aspects of photogrammetry. A typical problem would be to prepare a stand map of a nearby tract of about 1000 acres. The student would be furnished with recent photographs of a fairly large scale and of high quality. Modified infrared photographs (infrared with minus blue filter) at a scale of 1:12,000 are frequently used. Using these photographs, the student prepares a radial line plot and planimetric map, upon which all forest stands larger than 10 acres are delimited. Each stand unit must be classified by species, density, and height. Extensive field reconnaissance is ordinarily necessary.

As a following problem, the student might be required to estimate the volume of a portion of the timber mapped. For instance, he might be asked to locate sample plots on the photographs in the white pine stands, and estimate plot volume for each from a detailed measurement of tree height, crown diameter, and stand density. The same areas would then be located in the field and the plots actually established on the ground to provide a check of the photo interpretation and additional information not obtainable from the pictures.

Research Program

The problem of coordinating photogrammetric analysis with field work in forestry is exceedingly complex, and involves balancing two distinct types of sampling, each with different characteristics as to accuracy and type of information supplied. To provide at least a partial answer to this problem, research is being carried out at the Harvard Forest and is being supported in part by a grant from the Research Corporation of New York City. Graduate students interested in forest photogrammetry may participate in this research, either by working on the program on a part-time basis, or by handling a portion of the project as a research problem.

Much remains to be learned about the application of aerial photographs in forestry as the field is still in its early development. Among the other agencies working with problems in this field, the Harvard Forest has conducted studies in the types of photographs best suited for forestry use, the development of simple instruments for forestry use, and the application of aerial photographs in timber inventory. Some of this research has been been published in Photogrammetric Engineering and some through other outlets. A book on the use of aerial photographs in forestry is now under preparation. The outline of this book may be taken as an outline of the field of forestry applications of photogrammetry.

I. AERIAL PHOTOGRAPHS
- Types of aerial photographs
- Films, filters, and season of photography
- Scale and focal length
- Taking aerial photographs
- Obtaining and handling aerial photographs

II. AERIAL SURVEYING
- Displacement in single aerial photographs
- Overcoming displacement by radial line triangulation
- Transfer of detail from single photographs
- Stereoscopy
- Displacement in stereoscopic pairs of photographs
- Stereoscopic transfer of planimetric detail
- Topographic mapping from aerial photographs

III. PHOTO INTERPRETATION
- Techniques and principles of photo interpretation
- Site
- Tree species
- Stand density and crown diameter
- Tree heights
- Areas

IV. FORESTRY APPLICATIONS
- Forest mapping
- Indirect measurement of trees and stands
- Volume estimation from aerial photographs
- Use of photographs in controlling ground inventory
- Forest administration and other phases of forestry

Short Courses

In 1945 and 1946, the Harvard Forest offered a series of short courses in FOREST AERIAL PHOTOGRAPHY. These courses have now been discontinued. They were designed to acquaint professional foresters with recent advances in the field, and to provide them with a rudimentary knowledge of those aspects of photogrammetry dealing directly with forest management. Six regular two-week sections were given as well as six shorter special sections designed to meet the needs of individual agencies. Approximately 250 men took these courses, most of whom are practicing foresters. The regular instructors were Stephen H. Spurr, C. T. Brown, Jr., and Richard C. Rose of the Harvard Forest, and Edward S. Wood, Jr. of the Institute of Geographical Exploration. Experts from outside the University were frequently brought in for lectures and discussions.

It was found that two weeks was a very short time in which to cover the material desired, but that the professional foresters attending could not take a longer period off from their regular work. By restricting the amount of lecture material, however, and by placing emphasis upon the students doing the work themselves, it was felt that the purpose of the course could be accomplished within the time allotted.

Each student was given a set of six photographs (three each in two adjacent flight strips) of a local area, lens stereoscope, and parallax wedge. Using simple instruments and few materials, the students were required to construct a radial line plot by both transparent and mechanical templets; to prepare a planimetric map using the multiscope, camera lucida, reflecting projector, and secondary radial line triangulation; to deliniate forest types within a portion of the area, and to transfer type boundaries to the planimetric base map.

Forest photo interpretation exercises were concentrated upon a selected number of areas. Tree heights were measured by both shadow and parallax methods, crown diameters were measured, stand density determined on both a tree count and a crown closure basis, and areas measured with planimeter, dot grid, and transect devices. Measurements of trees and stands on the photographs were checked in the field, and used to estimate the volume of twelve selected white pine stands, which were also measured in the field. Practiced also was the location of plots on aerial photographs and the subsequent relocation of the same plots in the field.

At the conclusion of the course, the student retained the photographs issued him which,—together with the planimetric base map, type map, forest interpretation data, and two aerial timber cruises,—constituted his laboratory notes and exercises. He also retained the lens stereoscope and the parallax wedge, and, —it is hoped—the knowledge of how to construct adequate forest maps with these simple instruments, paper, pencils, and ink.

The program of the short course as finally evolved was as follows:

TWO-WEEK SHORT COURSE IN THE USE OF AERIAL PHOTOGRAPHS IN FORESTRY

First day

Lecture (2 hours): Types of aerial photographs. Verticals and obliques; contact prints, enlargements, and mosaics: calculation of photograph scale.

Laboratory: Calculation of scale on photographs furnished students. U.S.G.S. 7½ minute sheets used for control. Scale check lines are assigned to emphasize scale variation. Examples of various types of photographs are displayed and inspected.

Lecture (1½ hours): Photographs for forestry use. Specifications for vertical photographs to be used in forestry with emphasis on film, filter, season, scale, and focal length.

Laboratory: Single photographs are studied of the same area covered in different seasons with different film and filter combinations at different scales (Slab City Block, Harvard Forest). Differences in images of forest stands are noted.

Lecture (1 hour): Obtaining and handling photographs. Sources of existing and new photography; what to ask for: types of printing paper; how to store photographs.

Second day

Lecture (1 hour): Use of the stereoscope. Principles of stereoscopic vision. Alignment of photographs by stereo-base method. Types of stereoscopes. Stereoscopic vision with unaided eyes.

Laboratory (1 hour): Marking of principal and conjugate points on photographs furnished students. Orientation of photographs for study with lens stereoscope. Use of lens and mirror stereoscopes.

Lecture (1 hour): Principles of photo-interpretation. Importance of size, tone, texture, shadow pattern, and shape with special reference to forest detail.

Laboratory (1 hour): Interpretation of ten points on photographs selected by instructor. Points include such items as forest stands, gravel pit, sawdust pile, logged-over area, etc.

Field trip: Points interpreted in laboratory are visited in field to check photo-interpretation, build up correlation between photographic images and ground conditions, and to practice use of lens stereoscope in the field.

Third Day

Lecture (2 hours): Basic geometry of the aerial photograph. Distortion due to camera and lens, tilt, and relief. Development of the radial line assumption. Choice of control points. Ground control.

Laboratory: Picking control points and construction of tracing paper templets.

Lecture (1 hour): Radial line triangulation. Principles. Transparent, slotted, and mechanical templets.

Laboratory: Assembling transparent and mechanical templets. Drafting of radial line plot.

Fourth day

Lecture (2 hours): Measurement of parallax. Absolute parallax and differences in parallax. Parallax bar and the parallax wedge.

Laboratory: Practice with parallax wedge and parallax formula.

Lecture (1½ hours): Mapping and transfer devices. Secondary radial line triangulation; reflecting projector; camera lucida; multiscope.

Laboratory: Transfer of detail by simple instruments to radial line plot. Construction of simple planimetric map. Completed map is checked against U.S.G.S. 7½ minute sheet via camera lucida.

Fifth day

Lecture (1½ hours): Measurement of trees and stands. Crown diameters, density, and area. Techniques, accuracy, and limitations.

Laboratory: Areas are obtained by several different techniques on time-cost and accuracy comparison. Planimeter, transect devices, and dot grids are used.

Lecture (1 hour): Measurement of tree heights by shadow method. Technique, computations, and sources of error.

Laboratory: Check measurements of known trees. Computation of conversion curve for shadow-height method.

Sixth Day (Half Day)

Laboratory: Ten individual stands are designated. For each, tree heights are determined by parallax and shadow methods as well as crown diameters, number of trees, crown closure and areas. Photo-interpretation checked against known answers.

Seventh day (First day of second week)

Lecture (2 hours): Forest stand mapping. Principles of aerial forest mapping. Identification of tree species and site. Construction of classification code. Technique of combining photographic and ground work.

Laboratory: Construction of forest stand map of part of area mapped in previous work. Forest classification includes breakdown by species, height, density, and site. Field inspection of area provides check on photographic classification.

Eighth day

Laboratory and field: Completion of previous day's work.

Lecture (1½ hours): Aerial timber cruising—stand approach. Relation of stand volume to height, density, and site. Aerial stand volume tables. Field checking.

Laboratory: Estimation of volume of twelve white pine stands by stand unit approach.

Ninth day

Field: Check on aerial volume estimate made previous day. Each crew makes intensive check on one stand to provide check data and cursory inspection of other stands.

Lecture: Aerial timber cruising—plot approach. Class discussion of stand approach exercise. Theory practice of controlling a ground line-plot inventory by aerial photographs.

Laboratory: Lines of plots are established on planimetric map, transferred to contact prints, and interpreted.

Tenth day

Field: Each crew reestablished one line of plots on the ground, checking photo-interpretation and obtaining necessary volume data.

Laboratory: Computation of timber volumes from combination line plot survey.

Lecture (1 hour): Application of aerial timber cruises in commercial practice.

Eleventh day

Lecture (1 hour): Use of aerial photographs in forest administration. Office records, roads and railroad location, logging plans, hazard and damage surveys, silviculture, research.

Laboratory: Development of logging plan of area from photographs. Included is location of camp, skid roads, main roads, and determination of slope by parallax measurements.

Conference: Final review session.

COURSES IN THE USE OF AERIAL PHOTOGRAPHS IN FORESTRY OFFERED BY THE FORESTRY DEPARTMENT OF THE UNIVERSITY OF MAINE

Edwin L. Giddings, Instructor in Forestry

The Forestry Department at the University of Maine instituted, in the spring of 1946, some work in the use of aerial photographs in Forest Mensuration problems. The field covered was not extensive and the work was included in the regular advanced course in Forest Mensuration. In the following semester interest was sufficient to start a two-hour, one-semester course in Forest Aerial Photography and an equal number of geologists and foresters registered for this work.

The course in Forest Aerial Photography covered briefly the fields of characteristics of aerial photographs, mathematics of aerial photographs, stereoscopy, radial plots, interpretation of photographs, sources of and specifications for photographs, type mapping and timber estimating. Little laboratory equipment was available for use in this course but a new set of photographs of the timberlands in the vicinity of the University was purchased. These photos made it possible to work out problems in interpretation, mapping, and timber estimating most conveniently without providing extensive transportation facilities. It is planned to develop and continue this course during the coming year.

Because many of the students in the Forestry Department have been unable to schedule this separate course in Forest Aerial Photography, the required advanced course in Forest Mensuration will continue to include a limited amount of work on photographs in order that all of the forestry graduates will at least be acquainted with them and know something about their possibilities and limitations in timberland mapping and volume estimation work. None of the work of the Department is designed to produce professional photogrammetrists.

Three major shortages are making the work on aerial photographs difficult. The first is a shortage of experience in using photographs on mensuration work. This situation is to be expected and will, we hope, improve as time passes. The second shortage is a textbook designed to teach foresters what they should know about aerial photographs. It is believed that this difficulty will be eliminated in the near future and it will no longer be necessary to piece together a course from a group of books, pamphlets, magazine articles and allied literature. The third shortage is of low priced laboratory equipment for mapping work. The purchase of any amount of equipment on current budgets is most difficult and it would seem that some reasonably accurate equipment priced to fit the always limited funds of the foresters would be helpful.

The many advantages provided to foresters by aerial photographs make even the limited work so far offered by the Forestry Department of considerable interest to students and it is expected that the courses will be expanded as facilities become available.

AERIAL PHOTOGRAPHY AT THE NEW YORK STATE COLLEGE OF FORESTRY

John C. Sammi, Associate Professor of Forest Management

The presentation of a course dealing with the use of aerial photographs for forestry purposes at the New York State College of Forestry at Syracuse University is of particular interest in several respects. First, it indicates in one way how great has been the development of aerial photogrammetry since it is now branching out into such specialized fields as forestry. Second, the needs and requirements for forestry differ from those of "pure" aerial photogrammetry with respect to the photography and the equipment necessary. And third, we are in a very enviable position as a college at Syracuse University where a complete course in photogrammetry is thoroughly and interestingly presented under the direction of Professors Earl Church and Alfred Quinn. This last advantage is most helpful to us in that at least one of the courses in fundamentals at Syracuse University is a prerequisite to any course dealing with the forestry aspects of this subject.

The work that has been done and that is being done in forestry with respect to aerial photogrammetry primarily centers about timber cruising. Timber cruising to the forester is a broad term which pictures for him the processes of obtaining an estimate of the volume of timber on a given area. The situations encountered and the results desired are as variable as nature and economics can combine to develop them. From nature's standpoint the cruise may cover a sparse growth of cordwood material that would be marginal with respect to logging; an open stand of softwoods such as the pines of the southeastern part of the country cut up with bayous and hardwoods; the stands of the northeast with their many hardwood and softwood species often mixed; the relatively uniform growth of the California pine region; the dense stands of Douglas fir and redwood on the Pacific Coast. Under these different conditions and also within these very timber regions the shape or form of the trees vary from acre to acre due to the different growing conditions, with consequent variations in volume. The problem of the timber cruiser is to determine the volume of each species, to indicate on a map where it is located and to delineate the limits of the merchantable stand.

To perform this work from aerial photographs is a combination of photogrammetry and photo interpretation. The maps that are necessary can be made reasonably well from the usual 1:20,000 to 1:24,000 photographs that are available. The different types and stand density classes can also be delineated at these scales. The basic methods of mapping from the use of obliques to map development by the multiplex are so thoroughly presented in the courses at Syracuse University that the men coming to us are particularly well equipped in this phase of the work. Our problems then are primarily those of obtaining tree volumes from aerial photos and photo interpretation.

In the process of obtaining tree volumes the existing photographs are not entirely satisfactory but the cost of flying specifically for forestry purposes is for the most part prohibitive (even at present day lumber prices), therefore we must use any available vertical aerial photos. Volumes are obtained by measurement of tree height and crown diameter on aerial photos. Tree height is usually obtained by shadow measurements or by obtaining the parallax difference between the stereo base of the tree and top of the tree. Crown diameter is obtained by linear measurement of the crown image. The construction of the tables that give the volumes for these two arguments, or for either one of them, is a purely forestry problem. The photogrammetric problem is to devise a means of obtaining these two measurements with reasonable accuracy. We are using what has been developed in the part, a "shadow wedge" on a transparent base to measure the diameter of the crown and the shadow length by fitting the image between the two lines of the wedge and the parallax wedge which measures the differential parallax. The latter is used with a pocket stereoscope. The results obtained leave much to be desired. The demands of the work are such that speed is essential so a large number of trees must be measured in a given time. Accuracy is decidedly limited. The difficulties in height measurement are that the shadows fall on other trees in a dense stand or on sloping ground, and further, it is difficult to locate the base of the tree in using the parallax wedge on a dense stand and in estimating which mark on the parallax wedge is opposite the base of the tree for the lower coincidence and which mark is opposite the tip of the tree for the upper coincidence (the floating dot principle).

Another set of problems inherent to a satisfactory cruise is the recognition of the different tree species, both as individual trees and in groups (which the forester calls types). This photo interpretation work makes desirable a larger scale and some means of identifying each particular species. The work that has been done on this up to the present, indicates that with experience a large number of the coniferous trees can be identified by differences in the registered tone on the print which varies from gray to black. Very little positive identification of the broad leaved trees is possible as yet.

There are many other problems in the field of forestry that are at least partially solved by photo interpretation and about which a course is developing. There is the problem of road location for public travel, for log transportation to the sawmill, and for the purpose of throwing a fire crew into a previously inaccessible area. There is the problem of land lines which in many cases can be approximately located from photos particularly in those areas covered by the U. S. Land Office Survey. Incidentally, in this respect many of the old photos are invaluable since in some cases the land lines have been "moved" by individuals in recent years and the old photos show the original location. There is the problem of locating forest administrative sites and recreational, wildlife and grazing areas. There are the problems of land acquisition for public purposes, the delineation of timber trespass areas and the prevention of trespass by foresighted timber operators, the acquisition of fishing rights on various streams (the course of the stream being particularly well identified on the photos), the delineation of post-war work areas; the preparation of reports and records on different forest projects, the planning of fish ponds and game refuge areas. These problems have their own special requirements.

Our approach to these problems is twofold, in teaching and in research. The course work presented to our students so far has revolved about the practices of the U. S. Forest Service and the practices of the different timber consulting and timber operating companies. The photogrammetric methods are explained in class and problems developed on areas readily accessible to the College, which have been flown by the A.A.A. Field work is then performed to check the tree volume measurements made in the laboratory. The course covers area control; estimation of forest areas, types, condition classes and timber volume from aerial photographs with ground work pertaining to timber defects, aerial volume tables, composition of the stand and related factors, and to a limited extent, flying specifications. An additional course has already been found necessary. This will be devoted largely to photo interpretation with respect to forest fire control, range, timber and recreational management; the location of forest improvements and the allocation of the timber cut.

In research two members of the staff devote about one quarter of their allotted research time and funds to this work. Several of the graduate students have been assigned problems in this field. The work completed to date by these men has been exceptional. It is in the field of research however that we meet our greatest difficulties. While there are some problems that can be performed satisfactorily with the equipment and funds available there are many more than can only be accomplished by expensive experimentation. As an example it was developed at a recent Symposium on Aerial Photography in Forestry that one of the best scales on which aerial photographs could be taken, consistent with costs and other uses, is 1:15,840 (4 inches per mile). It was also brought out that the accuracy with which tree height could be measured depended on the parallax,—the greater the parallax the greater the accuracy of height determination. If then the scale is held constant, the parallax depends entirely on the air base distance and therefore on the *amount* of overlap of consecutive photos. The apparent answer to this is the use of K18 camera taking a 9 by 18 photo but with the 18 inches in the line of flight. This, with the conventional 60% overlap or 40% between the principal point and the conjugate principal point would develop a parallax of 7.2 inches in place of the 2.8 inches of the 7 by 9 photos. We should like to experiment with several pairs of such photos taken over a timbered area but the cost of such an experiment is prohibitive.

The American Society of Photogrammetry could aid materially in several respects in the teaching and research programs in the different educational institutions. The first need of any institution giving work in this field is to procure photos. A map showing the coverage by the different federal agencies is excellent for such purposes. A map of this type should however be brought up to date. As an example there is not shown on this map the area in New York State that was flown by the T. V. A. The private agencies could contribute appreciably to such a service by sending to some central organization outline maps showing the area covered each year. The date of coverage is of vital importance to most users of aerial photographs and particularly to foresters as the trees grow in volume each year while in some cases cutting operations remove whole stands of timber. Aid in research could be effective should it be possible to set up a committee that would direct inquiries to the best sources of information and would suggest where and how additional information could be obtained as in the parallax problem above. Photogrammetry has developed rapidly in the last twenty years. Its development in the next few decades will be greatly augmented by the two way exchange of ideas and problems.

ADDITIONAL COMMENTS

From Lewis F. Palmer, Associate Professor of Civil Engineering, University of Cincinnati: We give a three hour lecture course in the Principles of Photogrammetry and some laboratory time in a combined afternoon surveying course. We try to emphasize fundamentals rather than preparation to follow this field.

There is a definite need for a suitable small text giving procedures for scale checking, use of equipment, etc. with good small stereoscopic pairs which can be used with lens stereoscopes. We have 50 Austin Photo Interpretometers which are the small lens type with floating dot. The students are loaned these during the course for practice at home.

We also have eleven Fairchild F71 mirror type stereoscopes and parallax bar, an oblique sketchmaster.

The educational issue will be very interesting to us, and we will be looking forward to getting it.

From O. J. MARSHALL, Professor of Surveying and Geodesy, Ohio State University: In this connection I am forwarding a reprint of a paper by George H. Harding entitled "A New Era in Surveying and Mapping Curricula" reprinted from *Surveying and Mapping*, July-September 1946,* which expresses his views on the matter of course content, etc. I find myself very much in accord with his ideas. I am a little concerned about the objective mentioned in your letter to the effect that "all universities will be materially assisted in planning comprehensive courses in photogrammetry for undergraduate and graduate students." It is my opinion that a basic course in photogrammetry should be given to all civil engineering students. This is necessary if we are to teach modern, instead of outdated, mapping methods. However, I am not at all sure that graduate work in photogrammetry should be attempted in any but a very few universities where highly specialized equipment and personnel are available. I think that any attempt to teach graduate work in this specialized field in many of the smaller colleges might do the whole profession a dis-service.

From EDWARD S. WOOD, JR., Instructor in Aerophotography and Aerosurveying, Harvard University Institute of Geographical Exploration: The teaching aid that would be of the most value to me would be a reasonable facsimile of the Multiplex that would be available at a moderate price. While this instrument is extremely simple, my experience is that students have considerable difficulty in grasping the concept when pictures and diagrams are the only visual aids employed.

I feel that the work being undertaken by our committee will prove valuable not only to educational institutions, but also to the industry at large and I am looking forward to reading the various accounts in PHOTOGRAMMETRIC ENGINEERING.

From H. T. U. SMITH, Associate Professor of Geology, University of Kansas. My own thoughts on the role of aerial photos in the training of the geologist were recently set forth in an article in the Proceedings of the Geological Society of America. If this might possibly be of interest, I would be pleased to send a reprint.

In teaching elementary photogrammetry to geologists, I find that one of the principal needs is simplification. Much of the technical information in the field is so specialized and abstruse that it requires considerable predigestion before it becomes intelligible to students. There are comparatively few articles either in Photogrammetric Engineering or in the Manual to which I can refer the undergraduate students, even those with considerable engineering background, for elucidation of particular principles or procedures. It should be noted also, however, that there are some striking exceptions.

In the effort to attain simplification, I reduce the mathematics of elementary photogrammetry, so far as possible, to terms of descriptive geometry, which is

* Reprinted, pp. 395–401.

familiar to most of our students. Graphic methods, based on descriptive geometry, are sufficiently accurate for much geologic mapping, are easiest for the student to visualize. To aid further in the process of visualization, I make use of 3-dimensional models where possible.

I believe that one of the ways in which the Society could best aid teachers would be to supply movies, vectograph lantern slides, and models illustrating the principles and applications of photogrammetry. I recall seeing the movie on Trimetrogon Mapping in Washington more than a year ago, and felt that it, or an abridged version of it would be extremely helpful to teachers. However, I have not seen any indication of its being generally available. Similar movies illustrating other types of photogrammetric procedures, and explaining the operation of specific instruments, particularly those newly introduced, would be extremely helpful. Vectograph lantern slides would supplement the movies by permitting a more deliberate view of instruments and spatial relations. Vectoslides of models, if made from several angles, could be nearly as valuable as the models themselves. I am thinking now of models such as those designed by the U. S. Geological Survey to illustrate the spatial relations of trimetrogon photographs.

One of the inherent difficulties of teaching photogrammetry is the high cost of equipment. Next to actually examining the instrument itself, the best way for students to become familiar with equipment too expensive for their school to own is to see movies and slides describing and explaining it.

Another approach to the problem of cost would be thru the manufacturers of instruments. If they were to make substantial reductions in price to educational institutions, or offer instruments of simplified and less precise design for student use, at lower cost, I believe that it would be to their own advantage in the long run.

Possibly another partial solution to the problem of equipment would be to have certain of the more expensive instruments available to university departments for limited periods on a rental basis.

From P. H. UNDERWOOD, Professor of Surveying, Cornell University: At the present time our only required work in photogrammetry is given in our course in advanced surveying, where we try to cover the material in Breed and Hosmer's "Higher Surveying," Vol. II. The time we can devote to the subject is not as much as is warranted by the importance of this branch of surveying.

During the past twelve to fifteen years I have given a three-hour elective course in photogrammetry whenever there has been a demand for it. I have also supervised some graduate work in the subject.

Professor D. J. Belcher, who came here two years ago to take charge of the work in Highway Engineering is offering two elective courses on the determination of soil patterns from a study of aerial photographs, a subject of which he has made special studies.

I hope that we may be able to do some work with photographs at our Summer Survey Camp. There we may do work in radial control and determination of elevations by use of parallax measurements. We have a collection of photographs, several stereoscopes, a Talley-Fairchild stereocomparagraph, slotted templets, and a sketchmaster.

CONCLUSION

It is hoped that the preceding material will provoke further comments from all members of the Society.

In general, the opinions presented herein indicate a growing interest in the field of photogrammetry and a need for education at the college level. The educators are unanimous in their opinion that the student should be given work in the fundamental theories and practices in photogrammetry. The basic methods of map construction and the use of photographs can be demonstrated with very little equipment and require only the acquisition of several aerial photographs.

The employers of photogrammetrists have emphasized the need for a broad and thorough background in all phases of photogrammetry—surveying, map compilation, map reproduction and "engineering sense." Mr. Eliel has raised an additional point in his reference to the "art of photogrammetry."

It therefore appears obvious that industry does not want an automaton, but desires to have certain of its employees versatile and capable of following an entire mapping program from the first plans to the delivery of the final map. Such a conclusion leads to the questions, "Are employers prepared to adequately pay such trained personnel?", and "Does photogrammetry offer a professional future for an unlimited number of college graduates?" The members of the Society, employer, employee, teacher, and research expert, should give careful consideration to such ideas.

We believe that photography and photogrammetry are destined to play an important part in the scientific development of the world in the years to come, and through our colleges and universities we must guide, train and help the scientists of the future.

III. A Discussion of Some Basic Principles of Photogrammetry

Earl Church, Professor of Photogrammetry, Syracuse University

A group of basic principles of photogrammetry which have proved very useful in teaching, in that they suffice to solve virtually any analytical problem which can ever arise, can be stated as follows:

(1) $$S = \frac{H}{f}; \quad \text{or} \quad S = \frac{H-h}{f};$$

(2) $$X = \frac{H-h}{f}x, \qquad Y = \frac{H-h}{f}y;$$

(3) $$X = \frac{H-h}{f \sec t - y \sin t}x, \qquad Y = \frac{H-h}{f \sec t - y \sin t}y \cos t;$$

(4) $$X = \frac{B}{p}x, \qquad Y = \frac{B}{p}y, \qquad H-h = \frac{B}{p}f.$$

These simple principles based upon similar triangles and a bit of trigonometry, can be explained in a single class period. The various ramifications, covering rather completely most of the analytical phases of photogrammetry, can then be presented with great facility and never fail to prove profoundly interesting. A brief discussion of these four principles is given here.

1. Scale, Altitude of Exposure, etc.

(a) If an aerial photograph were taken with the camera axis exactly vertical over perfectly flat ground situated at sea-level then the "scale" of the photograph, expressed as the ratio between a ground distance and a corresponding photographic distance, would be

$$S = \frac{D}{d} = \frac{H}{f} \tag{1.1}$$

where H is the altitude of the camera lens at the instant of the exposure, measured from sea-level, and f is the focal length of the camera lens.

(b) If the photograph were exactly vertical, and taken over perfectly level ground situated at some other elevation than sea-level, say h, then the scale would be given by

$$S = \frac{D}{d} = \frac{H - h}{f}\,. \tag{1.2}$$

(c) A photograph, however, has no definite scale unless it is free from tilt and is taken over level terrain.

(d) The arithmetic methods of applying these simple expressions (1.1) and (1.2) to the flight mission problem are obvious. Finding exposure altitudes for obtaining certain desired scales for photographs of ground having a certain average altitude, finding areas covered by photographs of known dimensions taken from a certain altitude with a camera with a specified focal length, finding the distances between exposures to obtain a specified percent of longitudinal overlap between consecutive photographs, finding the time intervals between consecutive exposures, and finding the distance between flight lines to obtain a certain percent of lateral overlap between adjacent strips of photographs, all follow very simply from this first principle.

2. Relation Between Ground and Photographic Coordinates for Vertical Photographs

(a) Rectangular coordinates of any ground point can be found from measurements on a vertical photograph by the expressions

$$X = \frac{H - h}{f}x, \qquad Y = \frac{H - h}{f}y \tag{2.1}$$

where x and y are rectangular coordinates of the image on the photograph. Usually the image coordinates refer to the geometric axes of the photograph, and in this case the ground coordinates refer to rectangular axes defined by vertical planes containing the geometric axes of the photograph. In most problems the directions of the ground axes are of no consequence. It is noteworthy that these simple coordinate relationships in (2.1) properly take into account a complication often introduced known as "image displacement caused by topographic relief."

(b) If ground coordinates are thus found for two points from

$$\begin{aligned} X_1 &= \frac{H - h_1}{f}x_1, \qquad & Y_1 &= \frac{H - h_1}{f}y_1 \\ X_2 &= \frac{H - h_2}{f}x_2, \qquad & Y_2 &= \frac{H - h_2}{f}y_2 \end{aligned} \tag{2.2}$$

then the correct horizontal ground distance between the two points is

$$D_{1-2} = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}. \tag{2.3}$$

This computed distance is correct regardless of any difference of elevation between the two points. No "scale-point" is necessary for finding the correct length of the line.

(c) This principle can be used inversely to find the exact exposure altitude of a truly vertical photograph from a measured horizontal ground distance between two points whose elevations are known. In this case a value of H is found such that the ground coordinates found from (2.2) for the two points will make the distance found from (2.3) exactly equal to the measured or survey value. This is most easily done by trial, with an initial approximate value of H corrected proportionally to the change required in the computed distance, until there is obtained exactly the correct H which will give the correct value for the length of the control line. The first revision is sufficient. The value for H is of course absolutely correct, regardless of any difference in elevation between the two terminals of the control line.

(d) If the ground coordinates of the vertices of a plot of ground are found in the same manner from

$$\begin{aligned} X_1 &= \frac{H - h_1}{f} x_1, & Y_1 &= \frac{H - h_1}{f} y_1 \\ X_2 &= \frac{H - h_2}{f} x_2, & Y_2 &= \frac{H - h_2}{f} y_2 \\ &\cdots\cdots & &\cdots\cdots \\ X_n &= \frac{H - h_n}{f} x_n, & Y_n &= \frac{H - h_n}{f} y_n \end{aligned} \tag{2.4}$$

then the correct area of the plot is found by tabulating these ground coordinates

$$\begin{array}{cc} X_1 & Y_1 \\ X_2 & Y_2 \\ X_3 & Y_3 \\ \cdots & \cdots \\ X_n & Y_n \\ X_1 & Y_1 \end{array}$$

and finding

$$\tfrac{1}{2}[(X_1Y_2 + X_2Y_3 + \cdots + X_nY_1) - (Y_1X_2 + Y_2X_3 + \cdots + Y_nX_1)]. \tag{2.5}$$

This is a very quick method of finding the area of a piece of property from a vertical photograph. It gives an absolutely correct result, regardless of any differences of elevation between the several vertices. No planimeter is used and no "approximate" determination of "average scale" is required.

The term "scale data" for an aerial photograph is used to designate the quantities required for finding from measurements on the photograph the correct horizontal length of a ground line whose terminal elevations are known. A determination of the scale data is spoken of as the "scale-determination problem" for a photograph.

The "scale data" for a truly vertical photograph comprise only the exposure altitude H. Paragraph c above therefore explains the solution of the "scale determination problem" for a vertical photograph.

3. Relations Between Ground and Photographic Coordinates for Tilted Photographs

(a) On a tilted photograph, if x and y are the rectangular coordinates of the image of any point, referred to the nadir point of the photograph for the origin and the principal line vo from the nadir point to the principal point of the photograph as the positive y-axis, correct ground coordinates of the point are given by

$$X = \frac{H - h}{f \sec t - y \sin t} x, \qquad Y = \frac{H - h}{f \sec t - y \sin t} y \cos t. \tag{3.1}$$

Of course the image coordinates specified above for use in these formulas can be measured only after the tilt t and the swing s (photographic direction of the tilt, measured at the principal point from the positive y-axis of the photograph of the line to the nadir point of the photograph) have been determined. However, even in that case, if it is not convenient to mark the nadir point and principal line on the photograph for reference, it may be preferable to find the photographic coordinates specified above for formulas (3.1) by first measuring coordinates with reference to the geometric axes of the photograph and then obtaining new values to be used in (3.1) by a rotation and translation of axes by the expressions

$$\begin{aligned} \text{New } x &= x \cos \theta + y \sin \theta \\ \text{New } y &= - x \sin \theta + y \cos \theta + ov \end{aligned} \tag{3.2}$$

where θ equals $180° - s$ and where ov equals $f \tan t$.

(b) If ground coordinates are found by (3.1) for two points, thus

$$\begin{aligned} X_1 &= \frac{H - h_1}{f \sec t - y_1 \sin t} x_1, & Y_1 &= \frac{H - h_1}{f \sec t - y_1 \sin t} y_1 \cos t \\ X_2 &= \frac{H - h_2}{f \sec t - y_2 \sin t} x_2, & Y_2 &= \frac{H - h_2}{f \sec t - y_2 \sin t} y_2 \cos t \end{aligned} \tag{3.3}$$

then the correct horizontal distance between the two ground points is again given by

$$D_{1-2} = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}. \tag{3.4}$$

This distance is absolutely correct regardless of any difference in elevation between the two points, and regardless of the amount of the tilt of the photograph.

(c) Again, if formulas (3.1) or (3.3) are used to find the ground coordinates of, say n, vertices of a plot of ground, then the correct area of the plot can be found in exactly the same manner as shown before by formula (2.5). Areas found in this manner are absolutely correct regardless of any differences in elevations between the several vertices of the plot, and regardless of any amount of tilt in the photograph. No planimeter need be used, and no approximations regarding scale are required.

(d) In the case of a tilted photograph, if the tilt and the swing are known, the coordinate relationships in (3.1) may be employed in the reverse sense to determine the exact exposure altitude H from a measured ground distance between two points whose elevations are known.

Image coordinates of the two terminals of the control line are first measured with respect to the geometric axes of the photograph. Then formulas (3.2) are used to find the required photographic coordinates of the images referred to the nadir point as the origin and the principal line from the nadir point to the principal point as the positive y-axis. Then with these transformed image coordinates used in formulas (3.1) or (3.3), a value of H is computed by trial so that the ground coordinates found for the two points will cause formula (3.4) to give exactly the correct length for the control line. The first revision of an initial trial value of H, by correcting it proportionally to the change required in the computed distance between the two points, suffices to give a correct value of H which will make the computed length of the control line agree exactly with the measured distance.

The scale data for a tilted photograph comprise three quantities, the exposure altitude H, and values of the tilt and swing for the photograph. The method just described in this section shows how to complete the scale data determination for a tilted photograph when the tilt and swing are known in advance, by employing the measured length of one control line. The following section shows how to determine the tilt and the swing of the photograph from three control points.

(e) If a tilted aerial photograph contains the images a, b, and c, of three ground control points A, B, and C, whose horizontal and vertical positions designated by rectangular space coordinates (X_A, Y_A, Z_A), (X_B, Y_B, Z_B), and (X_C, Y_C, Z_C) have been determined by geodetic methods, then the exposure altitude, tilt, swing, or the complete scale data for the photograph, can be computed. The complete method will be briefly outlined here.

Let us first find the ground lengths of the three sides of the control triangle in the usual manner from

$$\begin{aligned} l_1 &= \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2} \\ l_2 &= \sqrt{(X_B - X_C)^2 + (Y_B - Y_C)^2} \\ l_3 &= \sqrt{(X_C - X_A)^2 + (Y_C - Y_A)^2}. \end{aligned} \tag{3.5}$$

Then the rectangular coordinates (x_a, y_a), (x_b, y_b), and (x_c, y_c) of the three images a, b, and c are measured on the photograph with respect to the geometric axes of the photograph.

Under the temporary assumption that the photograph is perfectly vertical or absolutely free from tilt, the control length l_1 for AB only is used to determine a value of H for the photograph, by the method explained in section 2(c). With this value for H, ground coordinates are computed for A, B, and C by formula (2.1) (In fact these have already been computed for A and B in the procedure for finding H), and lengths called l_2' and l_3' are computed for the distances BC and CA from these coordinates.

Next, under the temporary assumption that the photograph was so tilted that the nadir point is situated at (+10.00, 0), in which case $ov = 10.00$ mm., $t = \tan^{-1} 10/f$, and $s = 90°$, another value is found for H so that ground coordinates for A and B found from (3.1) or (3.3) now in the simplified form

$$\begin{aligned} X_A &= \frac{H - h_A}{f \sec t - (-x_a + 10)\sin t}\, y_a \\ Y_A &= \frac{H - h_A}{f \sec t - (-x_a + 10)\sin t}\, (-x_a + 10)\cos t \\ X_B &= \frac{H - h_B}{f \sec t - (-x_b + 10)\sin t}\, y_b \end{aligned} \tag{3.6}$$

$$Y_B = \frac{H - h_B}{f \sec t - (-x_b + 10) \sin t}(-x_b + 10) \cos t$$

will give a computed length for AB exactly equal to the control value l_1. This is a special case of the procedure described above under 3(d).

Then with this value of H, ground coordinates are again computed for A, B, and C by the formulas in (3.6) above (in fact these have already been computed for A and B in the procedure for finding H), and lengths called l_2'' and l_3'' are again computed from these coordinates for the lengths BC and CA.

Once more, under the temporary assumption that the photograph was so tilted that the nadir point is situated at the point (0,+10.00), in which case ov again equals 10.00 mm., $t = \tan^{-1} 10/f$, and this time $s = 0°$, another value for H is found so that ground coordinates for A and B from (3.1) or (3.3) now in the simplified form

$$\begin{aligned} X_A &= \frac{H - h_A}{f \sec t - (-y_a + 10) \sin t}(-x_a) \\ Y_A &= \frac{H - h_A}{f \sec t - (-y_a + 10) \sin t}(-y_a + 10) \cos t \\ X_B &= \frac{H - h_B}{f \sec t - (-y_b + 10) \sin t}(-x_b) \\ Y_B &= \frac{H - h_B}{f \sec t - (-y_b + 10) \sin t}(-y_b + 10) \cos t \end{aligned} \tag{3.7}$$

will give a computed length for AB exactly equal to the control value l_1. This again is a special case of the procedure described above under 3(d).

Then with this value of H, ground coordinates are once more computed for A, B, and C by formulas (3.7) above (Again those for A and B have already been computed in the procedure for finding H), and lengths called l_2''' and l_3''' are again computed from these coordinates for the lines BC and CA.

If the unknown but desired photographic coordinates of the actual nadir point of the photograph are designated by u and v, the following equations may obviously be set up:

$$\begin{aligned} l_2' + \frac{l_2'' - l_2'}{10} u + \frac{l_2''' - l_2'}{10} v &= l_2 \\ l_3' + \frac{l_3'' - l_3'}{10} u + \frac{l_3''' - l_3'}{10} v &= l_3. \end{aligned} \tag{3.8}$$

These simple linear equations can easily be solved for u and v, and these coordinates immediately determine the position of the actual nadir point on the photograph.

Then the tilt of the photograph is given by

$$\tan t = \frac{\sqrt{u^2 + v^2}}{f} \tag{3.9}$$

and the swing is given by

$$\tan s = u/v. \tag{3.10}$$

By means of these values for the tilt and the swing, the method described under 3(d) should be followed out to determine the final value of H from the control length l_1 of the line AB, and then the method of 3(a) should be followed to find ground coordinates of A, B, and C, and lengths from these coordinates for the lines BC and CA. This time these lengths for BC and CA should also agree with the control values l_2 and l_3.

(f) A simple variation of the methods of this Section 3 permits progressive computations either of tilts and swings or of complete scale data including tilts, swings, and exposure altitudes, through an entire strip of aerial photographs, without recourse to any ground surveying for control data except that for the initial photograph of the strip. The method for this progressive computation is described in some detail in number 18 of the series of bulletins on photogrammetry published by the Department of Photogrammetry at Syracuse University.

4. The Parallax Principle

(a) If two adjacent overlapping photographs of a flight strip are truly vertical and are exposed from exactly equal altitudes H; if B is the length of the air-base or the distance between the two exposure stations: if x and y are the rectangular coordinates of the image of a certain point on the left photograph, referred to the principal point for the origin and to an x-axis where the vertical plane containing the exposure stations intersects the plane of the left photograph; if the absolute parallax p for the corresponding ground point designates the difference $x-x'$ between the abscissa x on the left photograph and a corresponding abscissa x' of the conjugate image on the right photograph, referred to its principal point as the origin and to an x-axis where the vertical plane containing the exposure stations intersects the plane of the right photograph; then

$$X = \frac{B}{p}x, \qquad Y = \frac{B}{p}y, \qquad H - h = \frac{B}{p}f \tag{4.1}$$

where h is the elevation of the ground point, and X and Y are rectangular coordinates of the ground point referred to an origin at the left-hand ground-plumb-point.

(b) The conjugate principal points on two overlapping photographs can be marked very quickly and accurately by the use of an ordinary viewing stereoscope.

If a horizontal distance between any two ground points A and B is known, no matter what difference in elevation there may be between A and B, the length of the air-base B can be accurately determined without knowing the elevations of the ground points. For the rectangular coordinates (x_a, y_a) and (x_b, y_b) of the images a and b can be carefully measured on the left photograph, and the abscissas x_a' and x_b' for the corresponding images can be carefully measured on the right photograph; the parallaxes p_A and p_B can be found from x_a-x_a' and x_b-x_b', respectively; and a correct value of B can be found by trial such that

$$\begin{aligned} X_A &= \frac{B}{p_A}x_a, \qquad Y_A = \frac{B}{p_A}y_a \\ X_B &= \frac{B}{p_B}x_b, \qquad Y_B = \frac{B}{p_B}y_b \end{aligned} \tag{4.2}$$

will give a length for AB computed from these coordinates exactly equal to the control value. Any initial assumed value for B is corrected proportionally to whatever correction to the computed length of AB is required to give the measured control distance.

(c) The common exposure altitude H can then be determined from the known elevation h of any point, by measuring on the photographs the parallax p for this point and using the third formula of (4.1) in the form

$$H = \frac{B}{p} f + h. \tag{4.3}$$

(d) Any succeeding measurements to determine distances between any pairs of new points will give correct results by the application of formulas (4.1) to find ground coordinates of the points and by use of these coordinates to find the horizontal distances in the usual manner. Lengths determined in this manner are correct regardless of any differences in elevation between the terminals of the lines, and are found without determining any of the elevations unless they are desired.

(e) The area of a plot of ground can be found by first finding the ground coordinates of the vertices by means of the first two of the parallax formulas (4.1), and then finding the area from the coordinates as in section 2(d).

Any property area found in this manner is correct, regardless of any differences in elevation between any of the several vertices, and yet it can be computed without finding any of these elevations themselves. If the accuracy demanded does not warrant the computations of the tilts of the photographs, this method furnishes a very quick and highly satisfactory method of finding property areas. All errors caused by the so-called topographic relief displacements of images are eliminated.

These four basic principles of photogrammetry are interesting in many ways. It is rather amazing to see how the difficulties usually associated with the two obstacles in photogrammetry, namely tilt and topographic relief, and what is worse, their combination, seem to vanish in the face of these four little statements. No mention is made here of the isocenter, for after all, the conditions under which the geometric significance of the isocenter is important very seldom occur. No applications have been made here of projective geometry or vector analysis, because most of the objectives of those more elegant treatises seem to be accomplished by means of these simple fundamental principles.

A group of basic principles such as those discussed here can be helpful in the study of a subject like photogrammetry, particularly the elementary phases of the subject, if three conditions are fulfilled: first, if these principles are so chosen that they serve to open reasonably extensive and inclusive areas within the field being studied, or in other words if they cover the fundamental theory in the field completely enough to permit the solution of most of the types of problems which normally arise in practical applications of the theory; second, if they are simple enough to permit presentation with clarity and emphasis; and third, if they are few enough in number and of the proper nature to permit a student to acquire and to retain a unified and coherent conception of the subject. If the particular principles discussed in this paper fulfill any or all of these conditions, they may prove to be of interest to both students and teachers of photogrammetry.