a. *Use of three-dimensional models.* Doctor Colwell has pointed out the utility of such an aid in his very stimulating discussion and demonstration yesterday. This permits the student and the instructor to participate jointly.

b. *The use of three dimensional slides.* The novel and startling approach presented here in 1952 by Professor Kenneth Jackson has tremendous possibilities. If refined to the point—perhaps it already is—where it would permit the instructor and the class collectively to simulate conditions viewed through the stereoscope, the teaching of timber typing would be immensely simplified.

c. *The use of photo interpretation keys.* This will implant in the photo interpreter's mind a systematic method of approach and establish a subconscious check-list of clues.

d. *The use of stereograms.* This provides an opportunity for a photo interpreter to view and analyze a large number and variety of situations and solutions in a short time.

e. *Field demonstrations.* These are the ultimate in training. No forest photo interpreter ever reaches even a modest stage of efficiency without considerable cross-checking between photo and ground.

Conclusions

In summary, with energetic and expanding photogrammetry teaching and research programs in our forestry curricula, the efficiency of the field forester can be greatly advanced. To accomplish this, some adjustment is required within the curriculum which can be accomplished only if a sympathetic attitude exists on the part of forestry school administrators. Some still view the application of photogrammetry as being somewhat akin to an iceberg in the desert—very interesting, very novel; but probably shan't be with us long.

Because photogrammetry in forestry involves applications to a variety of specialties, the photogrammetrist's task is a difficult one and requires a great deal of work and the adoption of a scientific realistic attitude of approach. The best fluid in the world for lubricating the mechanism of such research and teaching programs as these, is the periodic sweat raised by the instructor on frequent trips to the field, there to view the situation in the cold, hard light of reality and practicality.

HIGHER EDUCATION IN PHOTOGRAMMETRY*

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BEFORE attempting to prognosticate the future of photogrammetric education, it might be well to briefly review its present situation. Surveying and mapping, and by inheritance, photogrammetry, have traditionally fallen within the domain of the civil engineering departments of colleges and universities, and the small proportion of practitioners in these fields who gained their basic knowledge through formal course work, normally hold degrees in civil engineering.

In the past fifteen years two factors have combined to create great changes in the formerly placid engineering colleges. The first of these is a tremendous increase in technology so that an engineering college graduate today is expected

* Presented March 8, 1955, at the Annual Meeting of the American Society of Photogrammetry, Washington, D. C. This is a part of the Panel on the Future of Photogrammetric Education.

to know a great deal more about many more subjects than his predecessor of a few years back. The second factor has been an increasing awareness on the part of both industry and educators that technical competence and specialized training are not enough. More and more organizations are coming to realize that a technically skilled, but intellectually sterile, individual soon becomes little better than an expensive piece of machinery. The university therefore has an obligation not only to introduce the student to a wide range of factual information, but also to develop in him the capacity to search for and to recognize the relationships and human significance in these facts. He must be equipped with the ethical and social concepts essential to a satisfying intellectual life, to a career consistent with public welfare, and to a sound professional attitude.

These are the traditional goals of a liberal arts education. The attempt to superimpose them on an already crowded technical curriculum has resulted in serious problems in all engineering schools. A number of different solutions and combinations of solutions have been employed. The engineering student normally carries up to one third more credit hours than the arts college major, and many schools have found it expedient to adopt a five-year engineering program. In others the range of specialization has been narrowed, so that civil engineering departments, for instance, now have options in highways, sanitation, hydraulics, structures, etc. Finally a serious attempt has been made to cut out those technical courses which are less essential.

Prominent among these casualties are courses in surveying and mapping. There is an almost universal trend to diminish the course and credit offerings in surveying in civil engineering departments. And this is as it should be, for not even a group of mappers can claim that surveying is more than a minor part of the usual civil engineer's requirements. It is true that a number of new courses in photogrammetry have been instituted in recent years because many educators have recognized that this is an important new tool, but the time allotted to the subject is usually deducted from the more conventional surveying courses. In addition a very few schools have organized options in higher surveying including photogrammetry. These are, nevertheless, counter to the trend and do not change the fact that the mapping sciences are in general neglected in the university curriculum.

Several questions immediately arise. What is the status of surveying and mapping as a science and profession? What are the numerical requirements for individuals trained in this field? How can these requirements best be met by the colleges and universities?

In answer to the first question, it is apparent that there are two fairly distinct levels of operation within the mapping sciences. On the practical level there are the land surveyors, the construction project surveyors, photogrammetric instrument operators, cartographic draftsmen, reproduction technicians, and many others. At the same time the technological advances of the last two decades have not passed by the field of earth sciences. There have been tremendous developments. These include as new instruments such as the optical theodolite, geodimeter, magnetometer, gravimeter, precision plotting instruments; in techniques are included aerial triangulation, electronic mensuration, gravity, star occultation and solar eclipse methods of determining the size and shape of the earth. Over and beyond these is the advent of sophisticated mathematical techniques and high speed computation which have made feasible attacking problems formerly impossible of solution.

The demand for personnel at the practical level far exceeds the supply. A committee of surveyors considering this problem in Ohio has stated that a hundred individuals a year could be absorbed in that state alone. The same committee stated that the average civil engineering graduate does not meet their requirements. Where then are they to look for men to fill these positions? It is probably true that a two year terminal course in college or a trade school could fit these individuals with the necessary technical knowledge. But such a plan would neglect the important social-humanistic studies which are necessary to a well-educated person. It would seem, therefore, that the training of such an individual would be a legitimate goal of a separate curriculum in geodetic science, or of an option within the civil engineering departments.

The Ohio State University has adopted the former course with the establishment of an undergraduate curriculum within the Geology Department in the College of Arts and Sciences. The courses in this curriculum are about equally divided between the normal social-humanistic requirements of the Arts College and the mathematics, physics, geology, and drawing courses necessary as background for the technical subjects in earth sciences. In the major sequence the student takes all of the surveying normally offered in the Civil Engineering Department plus three quarters each in photogrammetry, cartography, and geodesy.

In photogrammetry the first course presents the fundamental geometry of the aerial photograph starting with a single vertical photograph, and progressing to a stereo pair of vertical photos, a single tilted photograph and finally a stereo pair of tilted pictures. Laboratory exercises are devoted primarily to stereometer instrument techniques. The second course covers non-stereoscopic mapping techniques including radial line plot, mosaics, planimetric map compilation, rectification, tri-metrogon charting, and terrestrial photogrammetry. The third course is devoted to stereoscopic mapping, and includes as laboratory problems the compilation of a map with the Multiplex and Kelsh Plotter. The mathematics of relative and absolute orientation and model deformations are presented in lectures, and the principles of design and operation of modern stereoscopic instruments are developed by individual term papers.

The first course in cartography is a lecture and drawing course devoted to problems of map compilation, symbolization, grid systems, reproduction techniques and map making equipment. The second course is a survey and analysis of the various map series published by the United States government, foreign countries, and private organizations. It presents a graphical consideration of the major map projections. The third course is a mathematical treatment of the various map projections and grid systems.

In geodesy the first course presents the principles, purposes and methods of geodesy and introduces the student to the operation of modern geodetic instruments. The second course is devoted to the study of the adjustment of observations with applications to geodetic figures. In the third course subject matter of higher geodesy is introduced with lectures on the reference ellipsoid and geodetic lines, the computation of geographic and plane coordinates, the geoid and deflections of the vertical.

It is felt that the graduate of this program has attained sufficient factual knowledge to make him a valuable employee in any position having to do with earth sciences. At the same time his intellectual curiosity has been stimulated so that his education may be continued either by self development or formal graduate work leading to advanced degrees. The demand for individuals with these qualifications should justify the establishment of many more such undergraduate programs in the colleges and universities of the nation.

In considering the place of graduate education in geodetic science, two factors should be kept in mind. The first of these is that, for the time being at least, the demand for individuals at this level is relatively small. Probably a few hundred men per year could fill the entire requirements of the defense department, government and private mapping organizations. The point has been made time and again that European universities have turned out 10,000 geodetic engineers in the past twenty years. Each time this has been rebutted with the statement that European and United States needs are different. This is essentially true; but nevertheless a need does exist, it is growing every year, and it is not being satisfied.

A second, and extremely important, factor to be kept in mind is that the very wide range of knowledge applicable to modern geodetic science can hardly be encompassed by one man. Specialists are required in mathematics, electronics, geodesy, gravity and isostasy, photogrammetry, geophysics, etc.

Thus an organization contemplating a comprehensive graduate program in geodetic science is faced with the dilemma of small enrollment and large staff and equipment requirements. In order to provide the necessary concentration of students, equipment, and staff, it seems apparent that graduate education in this field should be centered in a very few schools.

In 1950, the Ohio State University found itself in a fortunate position in this regard. For a number of years the university had operated the Mapping and Charting Research Laboratory and had assembled a large staff of outstanding experts in the field. This group faced the necessity of recruiting young scientists to carry on the work of the laboratory. Encouraged by a number of outside agencies they proposed to the Board of Trustees the establishment of an institute to present high level work in geodetic science and allied courses. After thorough examination of the local and national needs and of the subject matter proposed, the Board of Trustees established the Institute of Geodesy, Photogrammetry, and Cartography.

The Institute is composed of interested staff members from the cooperating departments of Geology, Geography, Physics and Astronomy, Mathematics, and Civil Engineering, who present courses extracted from the regular catalog of the Graduate School. These are supplemented by special problems and advanced studies in photogrammetry, geodesy, electronic mensuration, and cartography which are presented by the staff of the Mapping and Charting Research Laboratory. This arrangement has permitted the Institute to present courses by such outstanding authorities as Drs. Felix Vening Meinesz, R. Roelofs, T. J. Kukkamaki, Bertil Hallert, Arthur Brandenberger, R. A. Hirvonen, and Simo Laurila. In addition individual lectures and symposia have been arranged which have included many experts from government and private agencies in this country. A final advantage is that qualified students are permitted to prepare theses and dissertations on contract research in the Mapping and Charting Research Laboratory. The proper spirit of scientific inquiry is thus promoted by serious work on actual existing problems.

In the field of photogrammetry in particular the special problems courses have been devoted to the following subjects: ground control methods for photogrammetry, terrestrial and non-topographic photogrammetry, the theory of errors for photogrammetry, and in the Spring Quarter this year a new course in photogrammetry for highway engineers will be presented. The advanced studies courses have presented work on the performance, theory of errors, and adjustment of aerial triangulation on first and second-order instruments. The wide experience of such men as Hallert and Brandenberger offers the best substitute for actual work on a first-order instrument, for it is a regrettable fact that as yet there does not exist a single first-order instrument in any educational institution in this country. The important subject of analytical photogrammetry is also presented in the advanced studies courses. The university is presently installing a computing laboratory which will utilize an IBM Card Programmed Calculator. The analytical photogrammetry course is presently being revised to adapt it to this important new development.

It is not suggested that the Ohio State system is the only solution to the problem of providing high level graduate instruction in the geodetic sciences, but the combination of teaching and research seems to be a highly effective means of assembling the necessary staff and equipment.

Those institutions which undertake to fill this serious lack on the American educational scene face a grave responsibility. The future recognition of geodetic science as a respected profession depends largely upon how well they fulfill their function.

NEWS NOTE

R-Theta Computer

The new R-Theta Computer of Photographic Survey Corporation Applied Research indicates to the pilot how many miles he is from base or target, and what direction he must steer to arrive there. For inventing the R-Theta, W/C J. G. Wright, DFC, one of Canada's outstanding navigation specialists, has been awarded the McKee Trans-Canada trophy for 1954, presented annually to the person who has contributed the most toward the advancement of Canadian aviation.

Designed for use in long-range, high speed aircraft, the unique instrument will operate just as efficiently in short-range, slower planes. It meets the pressing requirement for a compact electronic automatic navigation system.

There is now neither time nor working space on today's jet planes to keep a "dead reckoning" plot, nor feasible for military planes to fly straight as required to perform accurate navigation.

Although the aircraft's present position can be valuable information for the navigator, he usually requires this information to compute the direction to go to reach his destination and the time required to get there. For this reason it is much more valuable to find a means of expressing position as a distance and bearing from a given point.

The 37-pound compact instrument can be set to compute the distance and bearing of any other position desired, within the range limit of the device. Translated into the terms of a human navigator it is an automatic plotter and computer.

No matter what maneuvers the aircraft performs during flight, the pilot need only follow one line back to his starting point or the other to his destination. Distances of course, can be read from the lines, marked off in miles.

Calculations in the R-Theta Computer are performed automatically, entirely independent of radio transmissions. Distance and bearing of an alternate base can be set into the device by turning two knobs and depressing a switch, whereupon distance is indicated on a counter in the face of the instrument, and direction is shown by a double arrow. A single arrow in the display panel indicates the aircraft's track over the ground. When the pilot turns, until he brings the single arrow over the double one, he is flying toward his destination. Should the pilot wish to return to base, all he need do is lift a small lever marked "vector-add," and the double arrow swings around to the direction of the base from him.

One of the most interesting features of the instrument is what is referred to as its "memory," which remembers the aircraft's heading and speed during the time the navigator is adding or subtracting vectors.