International Symposium of Photogrammetry, Florence, 4 to 7 th Oct 1966

Invited Paper 5.2.

PROGRAMS AND METHODS OF TRAINING OF THE PHOTOGRAMMETRIC SPECIALISTS

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Photogrammetrists are needed in the following organisations:

1. Government topographic services,
2. Private cartographic and aerial survey companies,
3. Universities and other educational establishments,
4. Various government services; cadastre public works, geological services etc.,
5. Engineering organisations applying photogrammetric methods to a wide variety of measurements.

The technical staff needed in photogrammetry is:

a. University graduates with degrees in geodesy and surveying, or in engineering, mathematics or physics.
b. Experienced photogrammetrists with a secondary technical education, technical colleges etc. acting as chief of sections.
c. Operators.

We can consider now another point of view, viz. the variety of possibilities for education at different levels, and then try to find out how these can serve the needs of the groups 1-5 and how these possibilities for education fit in with the groups of staff a, b and c.

I consider it best to state in the beginning of my paper that there is no remarkable correlation between any of these 3 groups and that so far, except for the operators, the number of the categories a and b is per country still too small and furthermore the profession too young to come to a stabilised relation between education and professional position. The leading and responsible men in a public works or hydraulic engineering service are civil or hydraulic engineers. No government service will in principle deviate from this policy. A technological university knows this and knows the requirements of the profession. There is some cooperation between these two and the curriculum is adapted to the development of the engineering practice.

This is completely lacking in photogrammetry. Considering first the university level of education in photogrammetry we observe a rather wide variety. The easiest case offers the continent of Europe and the white countries of the former British empire, South Africa, Canada and Australia In their system of university

education the latter follow closer the non-latin countries of the European continent than the Anglo-saxon world.

In all those countries the technological universities offer specialised studies in geodesy, surveying and cartography, resulting in the degree of geodetic engineer or something similar. There photogrammetry is an important subject in the curriculum. In several universities chairs are occupied by geodesists who have specialized in photogrammetry, which, also in their teaching programme and scientific work, remains their main subject, although nearly always some other parts of the surveying curriculum are entrusted to them. For the student photogrammetry is one subject amongst many others. Important, however, is that mathematics, theory of errors and methods of adjustment, optics etc. which are basic disciplines for all practical work of the geodesist and surveyor give the geodetic engineer an excellent starting point in case he later wishes to use photogrammetry. That the curriculum in general does not go into all details of photogrammetry is not an exceptional case in university education. The same holds good for a civil engineer with a subject like railways or highways. He will realize the details whenever he enters into such a specialized field. That will also happen to the small number of geodetic engineers who really must become specialized photogrammetrists. Each young man fresh from the university needs still some so-called « in the service training ».

In these countries in which the surveyor, even the property — or cadastral surveyor, does not need a university education, but is formed in some secondary technical school or college with a long apprenticeship resulting in professional examinations, the situation is completely different. There the leading men in science and services are mainly civil engineers or mathematicians. The U.S.A. are an example of this situation; in some countries like Canada in which since recently a full degree in geodesy exists, the career of the property surveyor still goes along the old line. In the important US cartographic services there are mainly civil engineers who take the leading positions. This means that almost their entire specialised knowledge was obtained by self-study and in the service. It is obvious that in countries in which the surveyor has a lower social standing than the average university graduate in civil engineering, such services need already from this viewpoint for their leading positions, this kind of graduates as long as the university graduates in geodesy and cartography are not officially recognized as being of the same scientific and social level, as civil engineers and university graduates in mathematics.

In such cases the study of photogrammetry will be a part of a civil engineer's curriculum and in some universities, like Cornell and Illinois specialisation in photogrammetryy in the graduate school will be possible but resulting in a M. Sc. in civil engineering. Photogrammetry will get full attention in the cases where graduates are working for a doctorate. An article in Photogrammetric Engineering gives a description of the possibilities for the study of photogrammetry in US universities [1]. With only a few exceptions the available equipment is rather meager.

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[1] Prof. Robert H. Brock. Courses available in photogrammetry Phot. Engng. 1966 nr. 2; page 307-319.

In the United Kingdom the courses in photogrammetry are in full development. It is, however, a remarkable fact that the number of British students with Prof. Thompson in London University College with its good collection of modern photogrammetric instruments is small compared to that from abroad. This has to do with the fact that the leading positions in the cartographic services and companies are taken by formers officers and not by civil university graduates. Also this, however, may change as the reservoir of officers who served overseas is decreasing. A new phenomenen in the U. K. is that the geography departments of Universities are paying more attention to photogrammetry than before, partly perhaps to explore a new market for their students. The weak point for these geographers is their very limited knowledge of mathematics. It is obvious that on the European continent with its geodetic engineers this possibility for geographers is almost zero. There they are only users of airphotographs trained in protointerpretation for different purposes.

In Latin countries of the continent like Italy, however, no matter how high the level of photogrammetry may be inside and outside the university, the education on the top-level is not organised as part of the curriculum of geodesists, because the surveyors' profession in Italy is not at university level. This reduces the task of the professors in photogrammetry to teach the broad mass of civil and other engineers something of what can be obtained with photogrammetry and other precision measurements.

The conclusion is that there is no generally accepted system which is in accordance with the increasing importance and complexity of photogrammetric map production. Here the disadvantage comes to the fore of the rather limited number of scientifically educated photogrammetrists who are used in several countries, even in the bigger ones like USA.

Although a certain number of highly qualified photogrammetrists is badly needed for the higher positions, one of the consequences of what I indicated before is, that these important positions are sometimes occupied by technical staff with less specialized education. Can we demonstrate the opposite by pointing at the situation in the USSR where there are at least two high level schools as well as a considerable number of graduates in photogrammetry? [2]

In countries, however, where the education in photogrammetry is less developed and where there is nevertheless a need for scientists we have to face the problem of specialised institutes like in Moscov or the I.T.C. in Delft which can fill the gap.

Here, however, we might mention a more general problem in university education. We see everywhere the tendency to reduce the duration of courses which in some countries has increased up to 150% of the normal value. The best and most radical method is to reduce the curriculum by putting the main stress on basic disciplines like for the geodetic engineers on mathematics, statistics, theory of errors and adjustment and physics. Furthermore only so many applications to

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Robert D. Turpin. Some trends in photogrammetric education in the United States. Phot. Engng. 1960; page 127-130.

[2] N. J. Wentink. Soviet higher education in geodesy and photogrammetry. Photogrammetria 19 (1962-64) 4, p. 148-163.

geodesy, surveying, photogrammetry and cartography should be given as necessary to give the student the training and experience in the use and application of the fundamental disciplines. This should be done in such a way that at the same time something of the special atmosphere of the profession will be experienced.

It is obvious that with such a system certain gaps will occur. Is it, however, so useful to give in a university curriculum to geodesists a full course in photogrammetry if only a few surveyors will later be active in an aerial survey organisation. Would it then not be a wiser policy to give those men the possibility to follow, as the few who really need it, an advanced course, either in the university or in a specialised institute? The normal surveyor should know what photogrammetry means and above all what can be obtained with it. and no more.

Such courses can be taken at a different moment of one's career: either, in some cases, as a means for obtaining a M. Sc. directly after finishing the normal study or as a mi-career course, taken at the moment that the desirability arises. We must state, however, that our personal experience is that it is not a problem of a few weeks, but of a regular course of at least 6 months even for those who followed a full geodetic engineers course as is given at present on the European Continent.

This brings me to some conclusion about the education in photogrammetry at the toplevel. Is there such a basic difference between the countries in which photogrammetry is a subject in a full university curriculum for geodetic engineers and e.g. the Anglo-saxon and Latin countries where this is not the case? Should these countries consider themselves as backward and reorganize the curriculum according to the continental pattern as happens now in Canada and Australia? I don't believe so, on condition however, that they either accept the existing specialised courses abroad or include such special courses in the program of their universities.

It is in this respect desirable to give a warning to the new states and to the development countries. They should not copy old Europe, but follow the modern line of specialisation, for the time being making use of the existing facilities abroad. Their need for high level photogrammetrists is definitely too small, to justify the investment in men and equipment to organise this on a national basis, not even in cooperation with neighbouring countries.

Let us now consider the middle class technical staff, who e. g. in civil and hydraulic engineering are the alumni of technical colleges of different kind. Here we can be very short: in those schools photogrammetry counts for a little more than nothing. This is shown by textbooks in surveying used in these schools in different countries. Even those, coming from technical colleges for surveying have un insufficient knowledge of photogrammetry, even as operators. It means that alumni who enter into photogrammetry must be trained in the service. The other solution is that they make use of a specialized institute like the ITC.

The I.T.C. has received several students of this class from the German Staatsbauschule Abt. Vermessungswesen, from British Colleges, from the only Dutch Surveying College in Utrecht and from Israel. Those of them who have full matriculation, have finished the 3 or 4 years course in surveying at these colleges and have passed the ITC-examinations within 3 semesters with the qua-

lification « good » are granted a university degree, viz. the I.T.C. Degree of Bachelor of Science in Protogrammetric Engineering. Those without matriculation receive, after having passed the same examinations at college and at ITC a diploma as I.T.C. Photogrammetric Engineer.

This second category viz. those who enter a study without matriculation is the majority. We believe, however, that a still greater percentage of those working in photogrammetry on this level received their education only in the services in which they made their career, perhaps as selected from the operators, without following specialized courses.

Remains this third group: the operators.

The education of this category depends largely on the organisation of the service or enterprise. In case a group of for instance 4 restitution instruments is supervised by one photogrammetrist who checks every step in the procedure, the operator needs hardly any understanding about what he is doing. This is a system in use in services working with female operators. Because of the rapid change of personnel in such cases there is a tendency to reduce the cost of investment through training. Systematic training of a drill during 4 to 6 weeks will be sufficient. Since, however, the slogan « equal pay for male and female » found international recognition and application, the use of this system with female operators under supervision became less attractive.

We have the impression that in the larger services the operators are of such a level of training that they can carry out the plotting of normal models without assistance by supervisors. This naturally does not mean that their products do not need any check on precision, completeness, etc. This check, will nearly always be carried out with the completed pencil manuscript.

The question may be brought up whether there is a difference in the level of education of operators in the large US Services using mainly Kelshplotters and multiplex instruments compared with those working on the European continental type of instruments with optical train. The multiplex and Kelsh type seem to be easier to understand from the geometrical viewpoint. The whole restitution procedure is directly visible. An operator at the beginning of his training will understand immediately what happens in the instrument. This will even be so with the effect of the orientation movements if a gridplate is put in the plateholder.

We must realize, however, that this is only the first step in the evaluation of the difficulties or advantages of instruments from the operators point of view. An entirely different point of comparison is raised as soon as we consider the anaglyph observation as compared with that of the floating mark in optical train instruments.

To obtain the same precision in parallax measurement and in pointing requires for an anaglyph observation a higher level of skill.

Nevertheless, even an operator who has this skill after a thorough training cannot be considered to be a photogrammetrist. He is trained in the manipulations of orientation, but the most important part of his plotting is the interpretation of the details of the model. This requires an entirely different kind of skill and one of a higher level. Depending on the scale of the final product he must have less or more knowledge of geomorphology. For large scale maps with only little

generalisation the interpretation is limited to the necessity to distinguish the details which in general will not be too difficult with the scale of photography as used normally in this case. The required linear precision of the 3 coordinates will in general determine such a scale of photography, that the identification of details will not be difficult. In this respect the operator in a cadastral service using signalized boundary points has the easiest job as far as interpretation is concerned. For him the utmost linear precision and care in handling his plotting machine is the most important point.

The operator for medium and small scale topographic maps should have an entirely different education. The smaller the scale of the map, the more generalisation and the more important is a sufficient knowledge of geormophology and of those features of the landscape which must be represented on the map. We believe that in several training courses for operators not sufficient attention has been paid in the past to this aspect: perhaps this is the most time-consuming part of the training. In the large services the education in photo-interpretation is a subject of gradual development of knowledge and experience during the first year of productive work under the guidance and supervision of experienced topographic engineers.

It is obvious, however, that a training of operators following such a scheme is different from a 6-weeks' course for female operators. We consider this type of technicians as permanent membres of the technical staff who should be paid in accordance with their value for the service.

This brings us to another question. Should the photogrammetric operator also gain some experience in the terrain or should he remain an office-man like the great majority of the draughtsman?

We believe that the training of an operator in photo-interpretation will be more efficient for a man who served already in the field as assistant surveyor than for a young man just coming from, for instance, a secondary school. Although it must be considered as an advantage from the point of personnel policy to have operators serving also in the field, the fact that this is not so easy to organize in a service, makes that in many cases there is difference between the photogrammetric operator in the office and the fieldparties.

Some didactic problems
Theoretical formation

When considering first the highest level we must realise that photogrammetry has two basic aspects:

a) it is in its nature a geometrical problem, its theoryy deals with purely geometrical models.

b) the physical realisation of these models shows deficiencies and contradictions, which we consider as errors.

The consquence is that in a photogrammetric curriculum attention must be paid to descriptive and to projective geometry. Since in several engineering curriculae the descriptive geometry is either treated poorly or not at all, this subject

should be included in a specialized course in photogrammetry. The analytical geometry as treated in regular engineering courses is completely sufficient.

The second basic discipline gives even more difficulties. The theory of errors is in a rather rapid development. To understand the modern publications the knowledge of the classical method of least squares for adjustment of observations is no longer sufficient.

The theory of mathematical statistics with its determination of reliability of results and methods of testing of these are inevitable for a photogrammetrist, who wants to evaluate methods and their results.

That also applied mathematics belongs to the necessary tools for all this is clear. Calculus and matrix computations and training in the use of these in the theory of errors and adjustment will take up an important part of the time for the preparation of a reliable theoretical foundation.

A man who has mastered these subjects really will have no difficulty with pure photogrammetry. Methods and theory of orientation, aerial triangulation and the application of theory of errors to these subjects are, with the description of instruments, the most important subjects.

A special position is taken up by the techniques for the production of airphotographs and the evaluation of the quality of photographs from the viewpoints of precision and interpretability. This subject is of another character than those mentioned before, because physics and chemistry are playing here a more important role than mathematics. Nevertheless much attention should be paid to it as the quality of the photographic coverage and of the image are decisive for the economy of an aerial survey.

It is obvious that for the middle class technical staff the theoretical education will be limited to the principles of the mathematical foundation and will mainly consists of the photogrammetric technique as a part of a college curriculum for surveying or engineering.

The greatest problem on all levels are the exercises. The requirements for the operators are the severest and for the university level they can be lower. This is because for the operator it is his daily bread whereas the university graduate must be satisfied if he knows how to carry out the various operations without having a real skill. Furthermore a programme of photogrammetric exercises which gives the student no more than a knowledge of all operations requires between 600 and 900 hours. This is far more than in a normal European continental university course, even for geodetic engineers can be made available for this subject. Even with this full programme the alumnus is in the same position with photogrammetry as for instance a civil engineer with steel construction, which means that the practice must give him the skill for regular application.

Now we can consider it doubtful whether the engineer at the top really needs the skill which enables him to compete in productivity with his operators. As far as such a leading man has started at the bottom, he will be able to compete and, based on his better theoretical foundation to do it even better. There are, however, cases in government services where an allround geodetic engineer is appointed chief of a photogrammetric section. The guidance of a service will then be in more generale terms such as choice of methods, scale of photography etc.

although he in his position will depend on his executive staff for the evaluation of instruments etc. as far as he has no statistical data available about productivity.

There is another reason why the programme of exercises in photogrammetry in all university courses is rather poor, i. e. the limited collection of equipment. Specially the USA universities have hardly more than a few Kelsh plotters, multiplex instruments and stereoscopes. As far as stereoscopic optical train instruments and comparators are available, they are used for experimental work of the staff and graduate students. In some countries in Europe the situation is better because of the assistance by national funds. In such cases, however, the universities with a few exceptions, will only be equipped with products of the national industry. Also there, however, such equipment may hardly ever be used by an undergraduate student, but remain reserved for those working for a M. Sc. or for their Ph. D.

In conclusion the author believes that above all lack of time but also lack of equipment hampers the possibility to obtain graduates from the university with a B. Sc. or a geodetic engineers degree, who could be considered as real photogrammetrists. This fact is only a very special case of a general phenomenon which is due to specialisation. A choice has to be made either of longer university courses in order to specialize or to teach in the university first of all the basic principles as mentioned before. This could be done during a moderate period of study, leaving the thorough education in special subjects to post graduate courses or to specialized institutes. We believe this is a tendency in modern university education, specially in technical sciences as the present duration of courses which in some countries is 50% longer than the official duration, is unbearable.

Although the Delft International Training Centre was established as a contribution to the international technical assistance to the underdeveloped world, the experience in the past 15 years has shown that it has grown into its present position of an « International Institute for Aerial Survey and Earth Sciences I.T.C. » as it is called now, playing also the role of such a specialized institute for post graduate courses in addition to its original aim to provide development countries with photogrammetrists of all levels.

With this institute as example we found in several parts of the world efforts to establish similar schools. We mention only a few.

1. the Interamerican Geodetic Service has recently expanded its school in Panama, which originally operated on the technicians level for cartography in general, with an advanced course in photogrammetry for the Latin-American countries.
2. In Tokyo there is a special school for photo-interpretation with the aim to serve also the Asiatic countries of the Far East.
3. In Dehra Dun the course of the Indian Photo-Interpretation Institute in cooperation with the Delft I.T.C. has recently been started.
4. Plans exist to establish as an offspring of the U. N. regional Cartographic Conference a training centre for Aerial Survey in Bangkok and for production and for training in one of the African countries.
5. A Swiss Society « Gesellschaft zur Forderung der Photogrammetrie » has established in St. Gallen with support of Wild Heerbrugg a training school for photogrammetric operators.

Regarding equipment it is obvious that an institute for photo-interpretation is not very difficult. It is only a problem of good stereoscopes. The most expensive part are the vehicles for transportation during the fieldwork, necessary for checking the results of the photo-interpretation. This may be one of the reasons why there are more projects for photo-interpretation than for photogrammetry. Except in cases in which an industry is supporting a school in its own interest and makes the instruments available to governments of to the U. N. it will be a costly enterprise.

The I.T.C. can learn, however, that even with two or three different starting dates of classes and an increasing number of students (more than 20 to 25 in each class) a thorough analysis of the exercises can be very useful. Instead of using immediately for all exercises (such as measuring of vertical parallexes or topographic interpretation of images) the expensive plotting instruments it is desiderable to give the students a thorough training in all fundamental operations using simple instruments. For this purpose a special exercise instrument has been designed, that was called *stereoexin* (stereo-exercise-instrument). It consists of two separate parts. The lower part made of light metal carries two plateholders, each with a small Kappa-rotation and one of the plateholders can be shifted in x-direction. The whole lower part can be shifted in all directions but has a parallel guidance. A pencil is connected with this part either directly or with a pantograph. For easy shifting in the 4 corners are ball bearings on which this part rests during plotting formlines. It can, however, also be given a fixed position on the table. This can be an ordinary or a light table depending whether paper prints or diapositives are observed.

The upper part is a frame which has a fixed position on the table in such a way that in the mirror stereoscope, put on this frame, the photographs can be observed. This frame carries the floating marks, one of which can be used for measuring x-and the other for y-parallaxes. It is obvious that vertical distance between the photographs and the marks must be as as small as possible and that vertical observation must be guaranted [3].

With this instrument and the necessary photographs the following training programme is possible:

1. Study of the photograph with fiducial marks, principal point.
2. Stereoscopic image. Drawing of lines through identical principal points on each photograph.
3. Setting up of « Stereo-excin » with plateholder frame in movable and fixable position. A pair of paper prints of large scale photographs to be oriented on the plateholders.
4. Exercise in measuring of x-parallaxes. Six times measurements on 20 different points distributed over the stereoscopic image, obtained by shifting the plateholder frame. Stereoscope with binoculars with 4 x enlargements.

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[3] After this project for the Stereoxin was designed Dr. Jerie dicussed with the staff of the I.T.C. workshop the possibility to use floating marks of which the image is projected into the optical system. This idea and some others concluded in an entirely new design which in September-November 1966 is under construction.

5. Repeating the same exercise but with 10 points on small scale photographs (1:30 000 or smaller) of terrain with considerable difference in height.
6. Exercise in measuring of y-parallaxes using the same photographs as in ex. 4 and the same number of points with pencil marking of the points which were used (using large circles and some description of the location of the points).
7. Measuring the same y-parallaxes by means of the x-parallax screw after rotating the photographs 100 gr on the plateholder.
   Instead of (6 + 7), preferably the use of a stereoscope with Dove prism. Each of the 6 measurements carried out by means of the y-screw to be repeated directly after rotation of the prisms by means of the x-screw. For adjustment of the stereoscopy this requires either a thorough setting of the rectified photographs in advance or a slight movement of the stereoscope over the frame with floating marks.
8. The same exercise as (6 + 7)' but with the use of diapositives of photography smaller than 1:30 000 with moderate differences in height. The most difficult case will be obtained when using stereoscopes with 8-10 times enlargement and Dove prisms which give a very small field of view.
9. Exercise in point transfer. Use diapositives of large scale photographs of very flat terrain, such as meadows of so-called « polders ». Equipment consists of a light table, Zeiss snapmarker and a normal stereoscope with 4x enlargement. 15 points were pricked in advance by the staff in the left-hand diapositive. These points must be transferred. Furthermore with the use of 2 snapmarkers 15 identical points are marked at arbitrary points of the meadow.
10. Put the same diapositives in the stereoexin, and measure the x-and y-parallax in the marked points and in 4 points at a distance of 0,5 mm to the right, left, below and above the left pricked point. The average of these 4 points is free of influence of lack of orientation.
11. Plotting of formlines by means of shifting of the lower part of the stereoexin after introducing the x-parallaxes by shifting one plateholder. In order to be able to compare formlines the k-screw must be clambed and read to 0,005 g.
12. Exercise in topographic interpretation which is possible with different kinds of photographs using normal stereoscopes.

Such a program can be carried out until the student obtains such results as are in accordance with the tolerances set in advance. After this he can start the exercises at the photogrammetric instruments, such as orientation of all kinds, aerial triangulation and plotting.