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On the Accuracy of Photogrammetric Measurements of Buildings

Report on the Results of the Test "Dordrecht" Carried out by Commission C of the OEEPE

By J. Timmerman, P. A. Roos, K. Schürer and R. Förstner

Provisional Edition

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On the Accuracy of Photogrammetric Measurements of Buildings

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1. Organisation of the Test

1.1 Introduction

During the meeting of Commission C in November 1967 several suggestions regarding new test programmes were made. The measurement of clearly defined topographic features, such as buildings and walls, was considered to be a task of great practical importance. For this reason further details of this task were discussed and the goal of a programme was outlined. To prevent a repetition of tests carried out formerly, first the literature published in the field of photogrammetric building measurement was to be compiled and analysed. This work was carried out by Ir. J.A.J. M a r i s s e n , at that time member of the "Fotogrammetrische Dienst van het Kadaster", Den Haag (see also [1]). The compilation revealed that so far the influence of different cameras and different restitution instruments had primarily been investigated.

In later meetings of Commission C the suggestions were dealt with in detail. To keep the time for measuring and data processing within reasonable limits, it was agreed that only a few important parameters were to be included in the test. In addition it soon turned out that the restitution would lead to an enormous amount of work if the Restitution Centres involved would furnish maps only. For this reason a numerical solution of the problem was given preference. Considering that an optimal result depends in the first place on the terrestrial preparatory work and the air survey conditions, these factors were given special consideration in the planning of the test programme. In principle the test deals with the determination of the accuracy with which buildings can be measured in a photogrammetric model. For practical reasons also the accuracy of the terrestrial supplementary measurements, e.g. plumbings of roof lines, was to be determined. However, it is not the absolute position of the points that was to be determined but instead their position with respect to nearby signalised points. This way the high expenditure for terrestrial comparative measurements over a large area could be avoided. In the opinion of the Commission, the participating Restitution Centres should be free to use a restitution instrument of their own choice considering that the test was not aimed at comparing the accuracy of the various restitution instruments. First results of the test have already been published at the Symposium of Commission IV of the ISP (Paris 1974), the XIIIth International Congress of the ISP (Helsinki 1976), at the Congress of the Nederlands Genootschap voor Landmeetkunde (NGL) (Utrecht 1977) and at the XIVth International Congress of the ISP (Hamburg 1980) (see [2], [3], [12] and [13]).

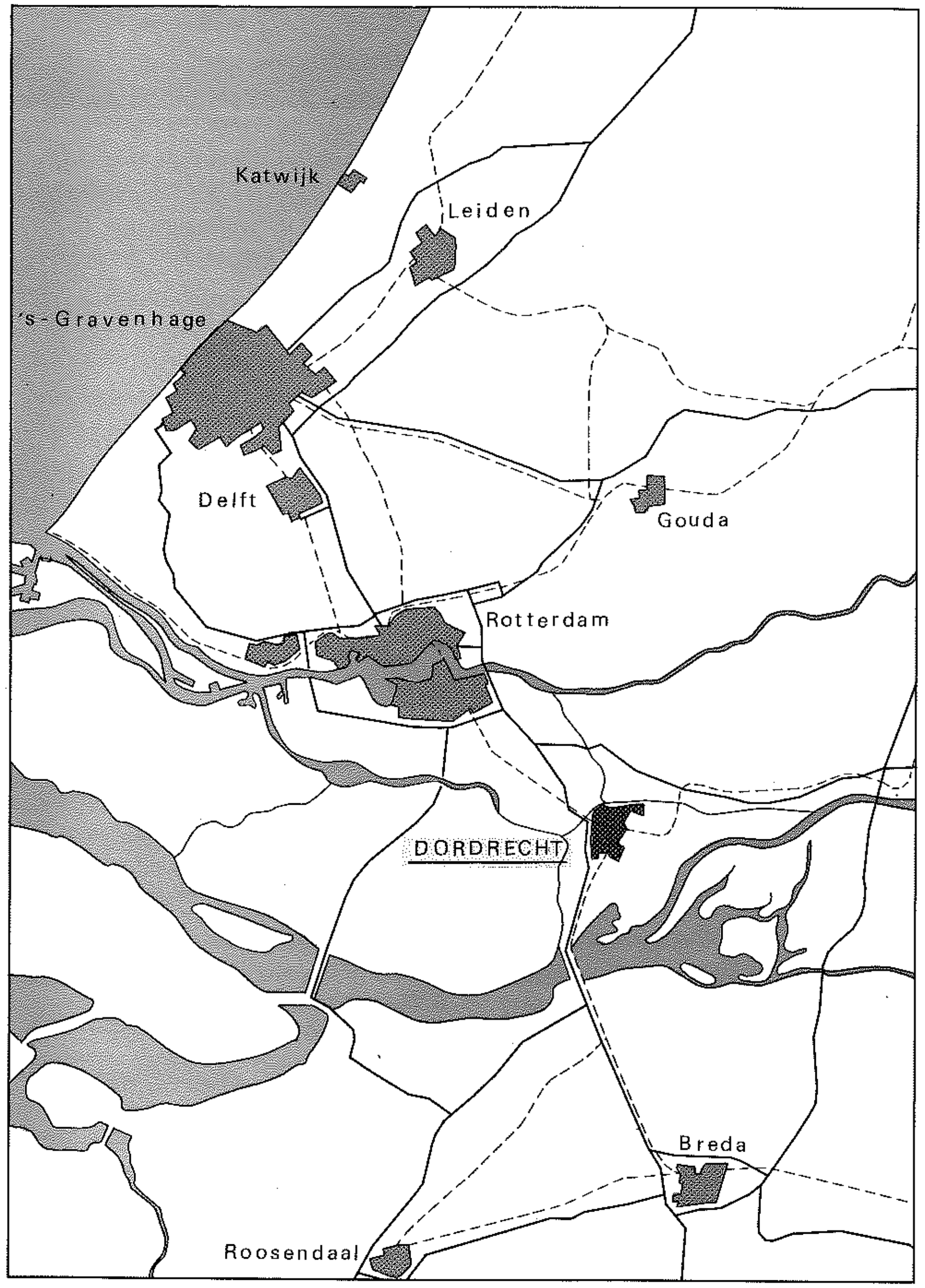


Figure 1 — Location of the test area of Dordrecht (Netherlands), general map 1 : 500 000

1.2 Test Programme

Based on the literature studies and discussions held in Commission C it was decided to formulate the test programme in such a manner that the following questions can be answered:

- with what degree of accuracy can points of a building be measured in a photogrammetric model?
- with what degree of accuracy are the required terrestrial supplementary measurements carried out?

The photogrammetric service of the Netherlands Cadastral Survey agreed to serve as "Pilot Centre". As test field a part of the city of Dordrecht (Netherlands) was chosen (see fig. 1) which offered the following advantages:

- it is within easy reach from The Hague, seat of the Pilot Centre at that time,
- it lies outside of airways and circling areas of civil and military aviation,
- the approach path is not too long.

Over the entire area, evenly distributed, groups of points belonging together, so-called "stations", were to be selected and measured. In these stations five kinds of points are distinguished, namely:

a-points: signalised points (on the ground)
b-points: building corners
c-points: roof corners
d-points: points on roof eaves
e-points: points on roof ridges (to be measured only photogrammetrically).

To be able to determine not only the accuracy of the photogrammetric measurements but also the accuracy of the terrestrial measurements, it was decided that the stations were to be measured terrestrially as well as photogrammetrically by five independent surveys. As connecting points between the photogrammetric and terrestrial measurements served the a-points signalised in the terrain.

To make better use of the extensive terrestrial preparatory work, the test was not to be limited to <u>one</u> scale but the parameter of image scale was to be included as well. For this purpose photographs at the scales of 1:6000 and 1:3500 were to be taken. This way a comparison of accuracies would become possible which is very important for the practice. In general photo flights are carried out only in sunny weather. One can easily imagine that under these conditions the illumination of the buildings does influence the photogrammetric measurements. Because of this, the possible influence of an azimuthal change of the direction of illumination on the photogrammetric measurement was to be determined as part of this experiment. For this reason two photogrammetric flights were to be carried out, one in the morning and one in the afternoon, with an interval between the two flights of not more than about 2 x 24 hours at the most. The most important parameters for the photogrammetric measurement thus are type of point, image scale and position of the sun.

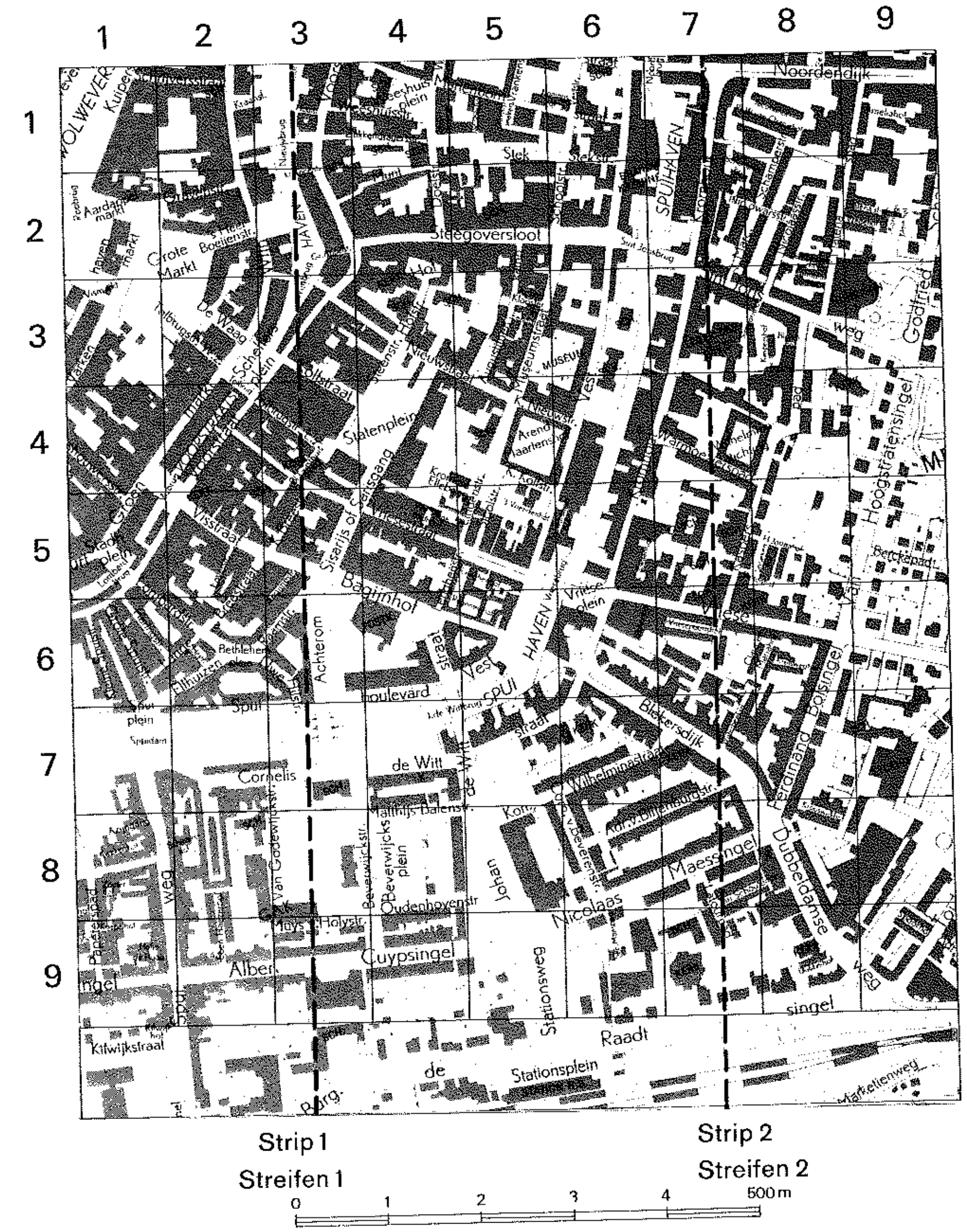


Figure 2 — The test area of Dordrecht and its subregions, scale 1 : 8000

Figure 3 — Example of the signalisation of an a-point

a) station 19

b) station 91

Figure 4 — Examples of terrestrial photographs of stations

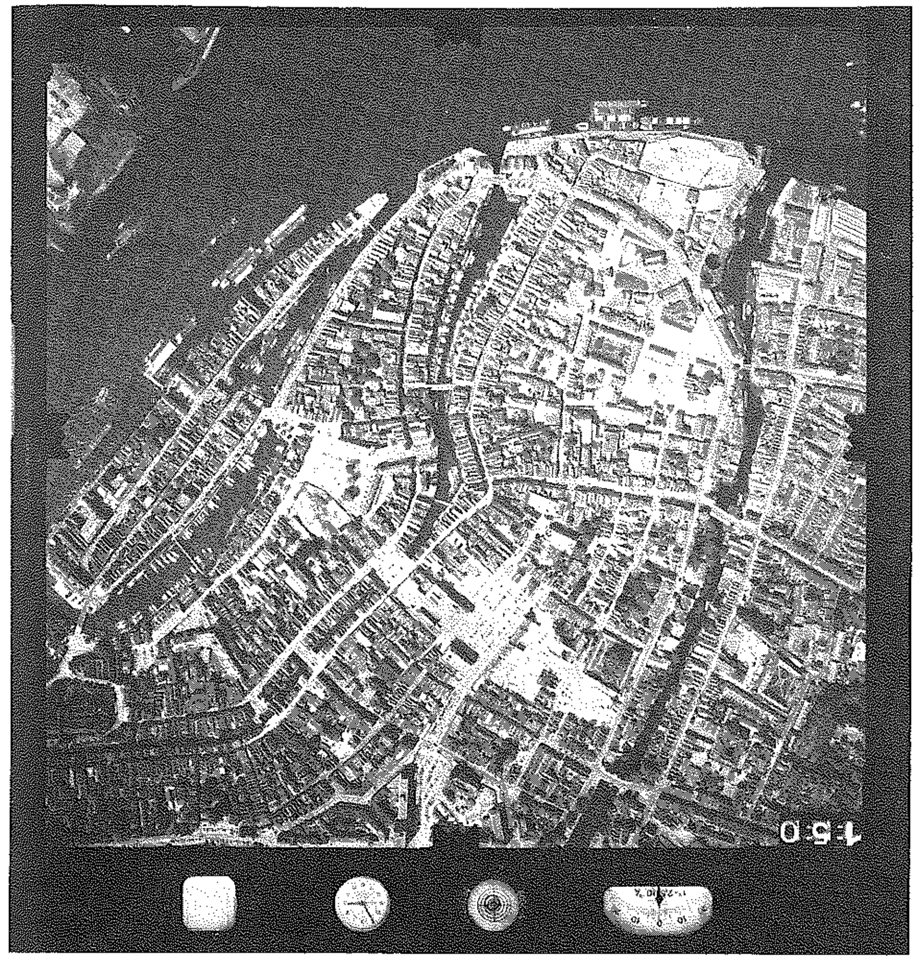


Figure 5 — Aerial photograph of Dordrecht, from flight at scale 1 : 6000, taken in the afternoon, reduced to 1 : 8000

Reflections on the accuracy with which the positions of buildings relative to each other can be established by photogrammetric means was not the point of this test since that problem can be tied directly to the problem of photogrammetric point determination, namely to the relative accuracy of two photogrammetrically determined points.

1.3 Arrangement and Aerial Photo Coverage of the Test Field

In compliance with these rules, the test field was finally set up in the winter of 1970/1971 and in the following spring. Because the test was limited to some few parameters and excluded the determination of the absolute position of the points, the test field was divided into "stations", as already mentioned before. To realise a regular distribution of these stations within the photogrammetric models, the test field was divided into 9 x 9 subregions of about 100 m x 100 m and in each subregion one station chosen (see fig. 2). Every station comprised 4 or 5 signalised points. For the terrestrial measurements these a-points were only marked with a nail, for the photogrammetric measurements they were marked by white disks, 25 cm in diameter. For contrast increase a 15 cm wide black ring was placed around every disk, the centering being guaranteed by a templet (see fig.3). By means of these signalised points the relative position of the building points within each station could later be determined by terrestrial as well as by photogrammetric measurements. In addition to the Pilot Centre, the Survey Department of the Community of Dordrecht also participated in the terrestrial work. During the preparatory work each station was photographed with a miniature camera in order to mark on the photographs the building elements to be measured and to preserve the conditions existing at that time (see fig. 4a and 4b).

As is usually done when city zones are photographed, a normal-angle camera was used for the photographic coverage. Considering that at that time many Restitution Centres were not in a position to restitute 30/23 photographs and that, moreover, such a camera was not yet available, a RMK 21/18 was used. The calibration of the camera was checked by the University of Technology at Delft. There were no complaints. The signalisation was completed on 19 May 1971. Subsequently the photo flight was assigned to K.L.M.-Aerocarto. The flights took place on 30 May and 1 June 1971. In accordance with given instructions, the flights were carried out at the scales 1:6000 and 1:3500 in the morning and in the afternoon (see fig. 5). In consideration of the building density and the visibility of the signalised points from the air, for both scales two flight strips were flown whose flight axes coincided in position (see fig. 2). For the flights the following equipment was used:

- Camera RMK 21/18
- Lens Topar
- Film Kodak XX
- Filter Yellow filter 2x

Additional data are compiled in table 1. In spite of the considerable overlap resulting from 1:6000 scale, the restitution was not limited to stations located in the centre of the model only. During the preparation of the test field in

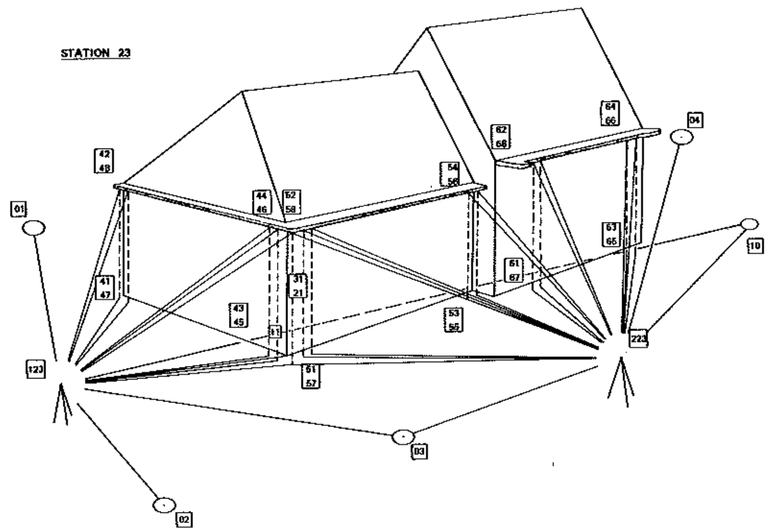
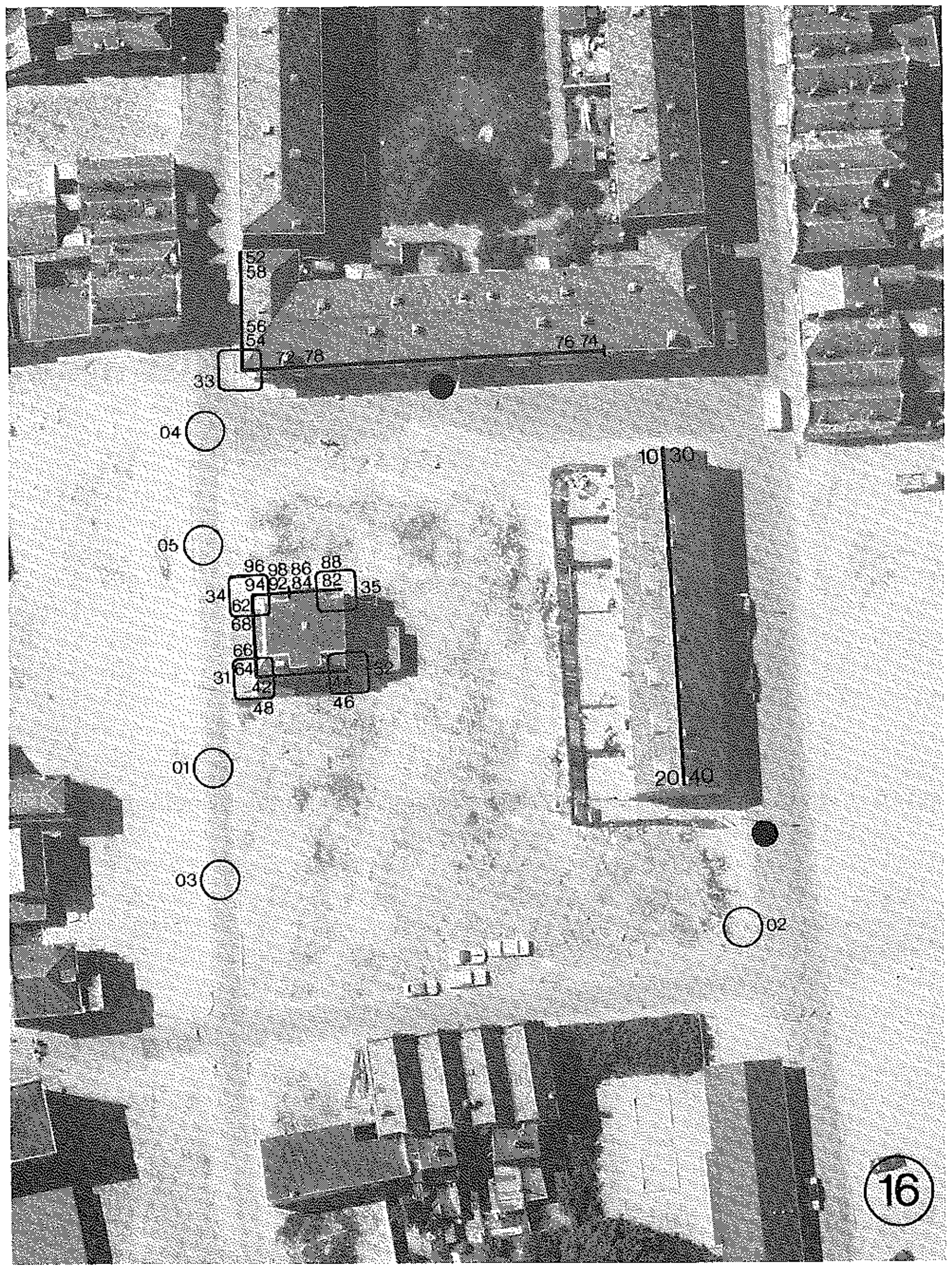
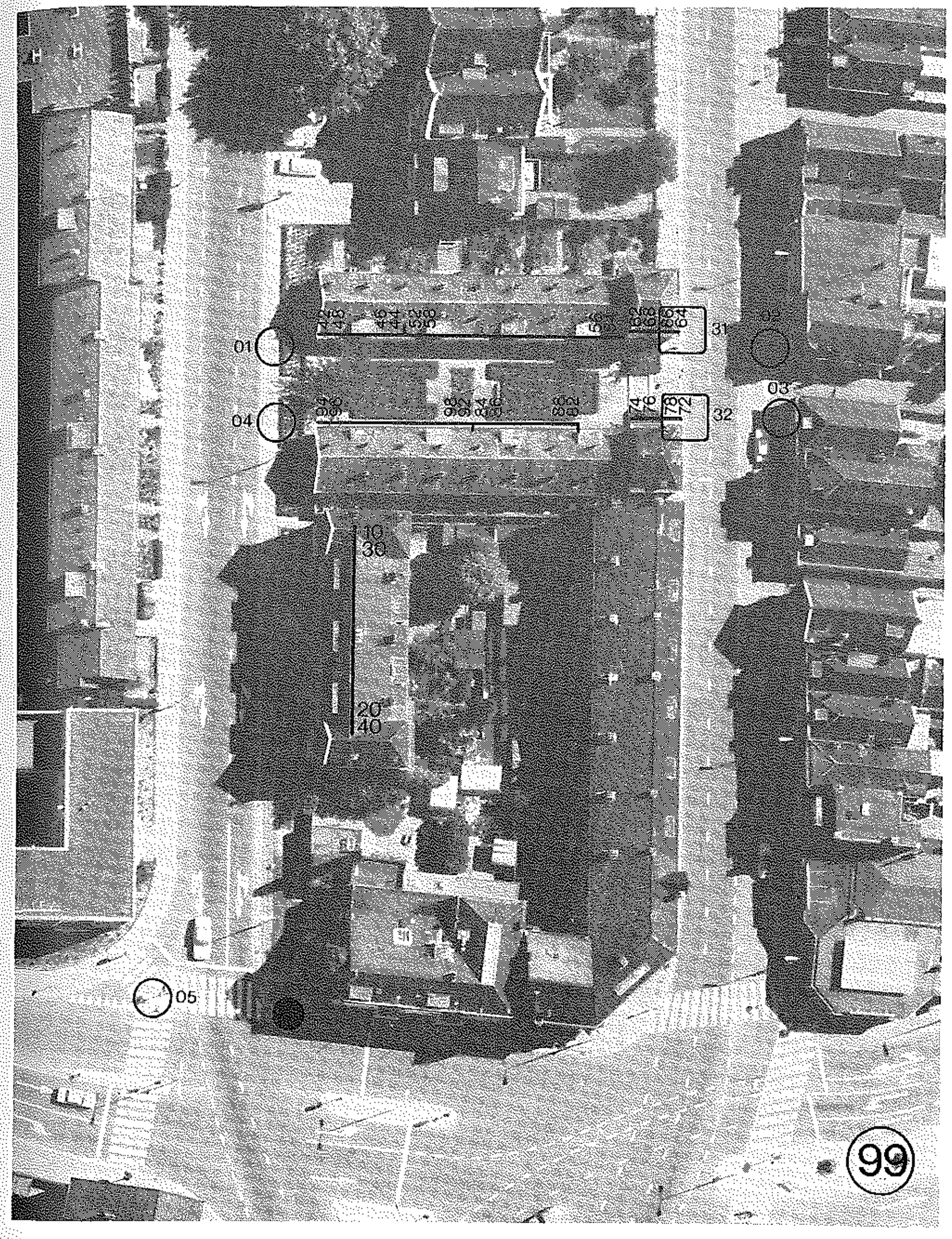


Figure 6 — Station with indication of the building elements and the point numbering



a) station 16

Figure 7 — Examples of aerial photographic enlargements at 1 : 700 scale (station sketches), reduced to approx. 1 : 750



b) station 99

Figure 7 *continued*

April and May, a survey team of the Community of Dordrecht spent 116 hours, and a survey engineer assigned to the Pilot Centre spent 184 hours, for the selection, monumentation and signalisation of the a-points.

2. Measurements

2.1 Introduction

From the very beginning of the test a numerical restitution and electronic data processing had been planned. This called for a strict encoding of the points according to station and type of point. This encoding had, of course, to be identical for the terrestrial and the photogrammetric measurements (see fig. 6). To be able to determine significant differences between the terrestrial and photogrammetric measurements with a satisfying degree of accuracy, the measurements had to be repeated five times, i.e. on the one hand, five different survey teams were to measure the station points by two independent series and, on the other hand, five Restitution Centres were to measure the same points by two independent series, too. If possible a second operator of the Restitution Centres was to repeat part of the measurements (see 2.3.2). This way another comparison would become possible.

2.2 Terrestrial Station Measurements

2.2.1 Preparatory Work

In spring 1971 the stations were selected and signalised under the direction of the Pilot Centre. The work was carried out by a survey team made available by the Survey Department of the City of Dordrecht. The preparatory work for the terrestrial measurements also included that, after the flight, the signalised points (a-points) were marked on a general map in such a manner that at every point one can see in which of the photo flights it is visible. By means of this map, the a-points to be used for each station could subsequently be selected in such a manner that the same points could be measured terrestrially as well as photogrammetrically. Only by proceeding this way the later comparison of the two measuring methods became possible.

The terrestrial measurements serve the determination of building elements in relation to the signalised points belonging to a station. The points and lines to be measured were - separately for each station - marked on enlargements of air photographs at 1:700 scale (fig. 7a and 7b). The Community of Dordrecht spent a total of 176 working hours for the determination of the control points. We profit of this occasion to thank its staff once more for its co-operation and valuable assistance.

2.2.2 Execution of the Measurements and Some Rules

In fall 1971, by order of the Director of the Netherlands Cadastre, the Cadastral Office Dordrecht carried out the terrestrial station measurements, i.e. the determination of the building elements with respect to the signalised a-points. First only provisional rules were given for these measurements. The final measuring instruction was established only after some test measurements had been made.

For the terrestrial measurements the method of optical distance measurement seemed best. On the one hand, this method is particularly well suited for measurements carried out in city centres and, on the other hand, numerical data processing presented no problem because a computing programme prepared by the Geodesy Department of the Delft Technical University was available. For the recording forms were used which had also been designed and supplied by the Geodesy Department. In order to possibly carry out five independent station measurements, the Netherlands Cadastral Survey engaged five survey teams consisting of four persons each. The equipment of each survey team comprised:

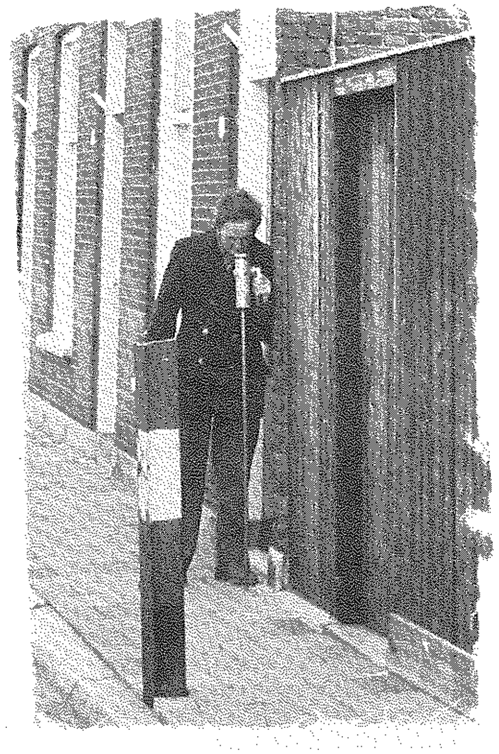
- 1 Kern tacheometer DK-RT;
- 1 roof plummet;
- a measuring instruction and a general map;
- photographs for each station annotated with the information on the elements to be measured (these elements are not yet indicated on fig. 4a and 4b);
- aerial photographic enlargements 1:700 for each station also annotated with the information on the elements to be measured (see fig. 7).

The measurements were carried out with the method of free stations (see also [4]). The horizontal angles and the tangents of the elevation angles were observed in one telescope only. In case more setup points were required for one station, then at successive setup points always two clearly defined identical points were additionally chosen for the connection of the measurements. In 85% of the cases not more than one setup point was required for one station. According to given instructions, the first survey team had to enter the numbers of the points on the aerial photographic enlargement. The point numbers consist of five figures:

The number of the setup point (continuous); the station number (from 11, ... 99); the coded type of point (a-, b-, c- or d-point) and a consecutive number.
The ground projections of the c- and d-points (roof points) served as auxiliary points for the survey of planimetry. This means that the terrestrially determined planimetric co-ordinates of the roof points include the errors of plumbing.

The terrestrial measurements offered the opportunity to test the suitability of different roof plummets. In photogrammetric practice these plummets are used to plumb and measure respectively projections of roof points or other highly located points of difficult access. For the Dordrecht test three types of plummets were available, built by Wild, Hensoldt and by the Rijkswaterstaat, Delft. Following a report submitted by the Director of the Cadastral Office at Dordrecht, the three plummets are characterised as follows:

Optically the Wild instrument has in general proved its worth. At low temperatures, however, the fluid compensator reacted on an average too slow. For Dutch weather conditions the plummet was too sensitive to the weather. The cardanic suspension of the centring rod was found to be somewhat too weak, the handle should be stronger. The connecting base between optical part and centring rod was also found too weak and the connection of the two parts too short. Moreover the entire instrument could be a little longer. Repeated plumbings resulted in a scattering of 1 to 2 cm.



a) Rijkswaterstaat instrument

b) Wild instrument

Figure 8 — Plumbing with roof plummet

The line of sight of the Hensoldt instrument is rigidly connected to the centring rod. Every movement of the rod presents itself to the eye strongly exaggerated in the visual field. Here, too, the connection between optical part and centring rod was found too weak and the centring rod too light. The length of the rod and the cardanic suspension satisfied the requirements. Repeated plumbings resulted, however, in a scattering of about 10 cm.

The plummet built by the Rijkswaterstaat is a simple tube with a line of sight. This tube is mounted on a range pole and placed in vertical position by means of a range pole level. The accuracy of the measurements corresponded approximately to the accuracy reached with the Wild instrument.

In view of the results obtained by the test measurements, the determination of the roof corners and roof eaves was carried out by the plummet built by the Rijkswaterstaat and by some Wild plummets (fig. 8a and 8b). The third plummet was not used because of its large scatterings.

On the whole, approx. 11 000 point measurements were taken for 71 stations. Unfortunately 10 of the originally selected stations could not be used because buildings or signals had been destroyed prior to the flight or because signals were not visible on the aerial photographs. On the average every survey team needed about 16 working days to carry out its measurements which amounts to a total of 2500 working hours.

2.3 Photogrammetric Measurements

2.3.1 Preparatory Work

Ten Restitution Centres took part in the photogrammetric measurements. A list of these Restitution Centres, the instruments used, the number of the models measured, etc. is given in table 2. A list of the restitutions including the number of the measured stations is given in table 3. Each restitution contains models originating from two flight strips. The work was distributed in such a manner that the Restitution Centres 0 - 4 measured the models of strip 1 and the Restitution Centres 5 - 9 the models of strip 2. The principal restitutions are the restitutions 1 - 4 carried out by the first operator. Here every model was independently measured five times. The restitutions 5 - 8 are repetitions of the restitutions 1 - 4 but carried out by another operator. Considering that not all of the Restitution Centres could make a 2nd operator available, only some of the planned models were measured twice independently. The stations had been evenly distributed over the model thereby always paying attention that the a-points were visible. To guarantee the completeness and the correct encoding of the photogrammetric measurements, a list of numbers of the points to be measured in forward and backward direction was compiled for every model and every operator.

Originally it had been planned to perform the photogrammetric and terrestrial measurements at the same time but later on it turned out that this was not feasible because of the necessary uniform numbering of the points. As mentioned before these point numbers had been assigned during the terrestrial measurement carried out by the first survey team. This time had been chosen to dispose of as many identical a-points as possible.

2.3.2 Rules for the Photogrammetric Measurements

To reach a standardization of the photogrammetric measurements, precise rules had to be observed which applied in particular to the Restitution Centres. These rules read for the Dordrecht test as follows:

1) The measurements are to be divided up among the Restitution Centres in such a manner that each Centre measures 12 models, i.e. 2 models at the scale of 1:6000 and 4 models at the scale of 1:3500, once during the flight in the morning and once during the flight in the afternoon. The models at small scale are to be measured first.

2) Every Restitution Centre is provided with the following material:
   - 1 set of diapositives on film;
   - lists of the points to be measured in each model;
   - general map 1:2500 depicting the test field with the marked stations;
   - general map 1:2500 depicting the control points and the signalised a-points;
   - aerial photographic enlargements 1:700 (station sketches) (see fig. 7);
   - terrestrial photographs of the stations (see fig. 4);
   - distorsion curve and other calibration data of the camera;
   - co-ordinates of the 4 control points per model, for the (preliminary) absolute orientation of the models.

3) The choice of the restitution instrument is left to the Restitution Centres.

4) The method of relative orientation is left open. The absolute orientation is carried out numerically at a later time, based on the given control points. The model scale is to be chosen as large as possible.

5) The heights are - like the planimetric co-ordinates x, y - to be recorded in "millimetres in the model".

6) The models are to be measured in two series. The series are to be carried out at different times - but without too long an interval - so that the two settings of one point are not carried out immediately one after the other.

7) Provided the Restitution Centres are in the position to do so, of each flight one model is to be measured (in two series) in the same instrument by a second operator. This is to take place only after a new inner and relative orientation of the photos.

8) The measurements are to be carried out in the order as indicated on the list of points to be measured for each station.

9) Upon completion of the measurements (for one scale) every Restitution Centre sends a copy of the original measurements to the Pilot Centre and informs the President. The Pilot Centre must ensure that all restitutions are complete and clear. If need be it proposes to the President how the restitutions are to be corrected or completed. For this the most simple way is to be chosen.

10) The final report must contain the following information:
   - Restitution instrument and recording devices used, correction plates, type and size of the measuring mark, model scale.
   - Method of relative orientation.
   - Description of the execution of work, time expenditure, additional comments on operator and his experience, instrument adjustment, film shrinkage, residual parallaxes, reading accuracy and the like.

11) If a Restitution Centre considers it useful or necessary to change a rule, it may suggest so to the President of the Commission before the actual work is started.

At a later time it turned out that - contrary to rule 1 - for strip 1 of restitution 4 (flight at 1:3500 in the afternoon) 6 models were required instead of 4 to cover the area (see table 2).

2.3.3 Measuring Results of the Restitution Centres

In February 1972, the Restitution Centres received the material necessary for the measurements (see 2.3.2, item 2). Some data on the restitutions are contained in tables 2 and 3. The indicated restitution times must be looked at critically because the final reports do not always clearly indicate what parts of the entire work are actually included in these reports. All Restitution Centres employed experienced operators well familiar with the instruments used. Before the measurements were started all instruments were, though according to different methods, tested and, if necessary, adjusted. All operators agreed unanimously that the identification of the points at 1:6000 image scale is bad. This also applies to the signalised a-points.

For practical work a larger image scale is to be preferred. In some models the number of discarded points is very large, in some cases even very poorly defined points had been measured. At the end of February 1973, the Pilot Centre disposed of the results of all measurements and computations carried out by the Restitution Centres.

3. Computation of the Co-ordinates

3.1 Computing Programme

In July 1970, Mr. van G e n t from the Photogrammetric Service of the Netherlands Cadastre forwarded the draft for a test programme on building measurements to the members of Commission C. Following a meeting which was also attended by representatives of some Restitution Centres, Mr. van Gent submitted in October a proposal for the computations required for the analysis of the results. In December, the commission discussed this and asked Mr. van Gent to draw up a computing programme. To ensure that, at a later time, significant differences between the terrestrial and photogrammetric measurements could be determined, Messrs. L i g t e r i n k and D u b b e l t from the Technical University at Delft suggested in May 1971 an extension of the measuring programme (heights) which also meant an extension of the computing programme. In June, the commission discussed all details of the computing work, thereby placing special emphasis on the possibilities of a comparison of lines (roof eaves). Following this discussion, the President of the commission prepared a new comprehensive draft (version of 1 September 1971) and forwarded it to the people concerned. At another meeting the comments sent to the President were discussed and the programme was once more slightly altered. On 30 December 1971 the final version was available. The Steering Committee raised no objections to the suggested experiment.

The computing programme assumes that for every station and for every restitution the terrestrially and photogrammetrically determined co-ordinates are already available in a uniform local net. Proceeding from this assumption, the programme includes - in shortened form - the following computations:

Item 1. Terrestrial measurements
For each station the co-ordinates of the a-, b-, c- and d-points are determined terrestrially by 5 independent measurements. The double measurements taken by every survey team are averaged and regarded as one measurement.

Item 1.1 Computation of the terrestrial co-ordinates of the a-points
The planimetric co-ordinates x and y of the measurements 1 - 5 are averaged. These arithmetic mean values are the final co-ordinates.

The heights z of the measurements 1 - 5 are also averaged. These arithmetic mean values are the final heights.

Item 1.2 Computation of the terrestrial co-ordinates of the b- and c-points
Simultaneously with the a-points (see item 1.1) the planimetric co-ordinates x and y of the b- and c-points of the measurements 1 - 5 are transformed into the system of the mean values of the a-points by a linear conformal transformation. Subsequently the co-ordinates of the single b- and c-points are averaged. The arithmetic mean values are the final co-ordinates.

Simultaneously with the fitting in of the heights z of the a-points into the mean values, the heights of the b- and c-points are also displaced in parallel direction. Subsequently the heights for every point are averaged. These arithmetic mean values are the final heights.

Item 1.3 Determination of the terrestrial d-lines
Every d-line is determined by two d-points. The adjusted straight line through the 2 x 5 = 10 d-points runs through the centre of gravity of the 10 points. If x', y' are the co-ordinates of the d-points with respect to the centre of gravity, then we obtain the azimuth α of the d-line from the equation

$$\tan 2\alpha = \frac{2[x'y']}{[x'x'] - [y'y']} \qquad (31.01)$$

In doing so it is assumed that the square sum of the perpendicular distances from the points to the straight line becomes a minimum.

A similar result is obtained when the co-ordinates of the five d-points at the beginning of the d-line and the co-ordinates of the five d-points at the end of the d-line are averaged. By means of these two centres of gravity the d-line is determined.

To determine the heights of the d-lines, the x- and y-co-ordinates of the d-points are to be transformed into the adjusted straight (planimetry). In case the heights z and the transformed planimetric co-ordinates $\bar{x}$ are referred to the centre of gravity again, we obtain the inclination β of the d-line as compared to the horizontal plane from the equation:

$$\tan \beta = \frac{[\bar{x}'z']}{[\bar{x}'\bar{x}']} \qquad (31.02)$$

Considering that the $\bar{y}$-values are small and in this case practically of no importance, we can also say:

$$\bar{x} = \frac{x'}{\cos \alpha}\ , \qquad (31.03)$$

(see equation (31.01)). This way we obtain from equation (31.02)

$$\tan \beta = \frac{[x'z']}{[x'x']} \cos \alpha \qquad (31.04)$$

Item 2. Photogrammetric measurements of different Restitution Centres
For every station the co-ordinates of the a-, b-, c-, d- and e-points were independently measured by five different Restitution Centres. For the a-, b- and c-points the two series of each restitution were averaged and taken as one measurement. We refrain from treating the five independent photogrammetric restitutions the same way as the five terrestrial measurements.

Item 2.1 Transformation of the photogrammetrically measured co-ordinates into the system of the terrestrially determined a-points
For each station we transformed in linear conformal manner the photogrammetrically measured planimetric co-ordinates x and y of all points of the measurements 1 - 5 by means of the co-ordinates of the a-points into the terrestrial system. As values of comparison served the mean values of all five terrestrial measurements according to item 1.1.

The heights z of all points of the photogrammetric measurements 1 - 5 were for each station also converted into the terrestrial system by a parallel displacement with the aid of the a-points.

Item 2.2 Computation of the photogrammetric co-ordinates of the b- and c-points
Simultaneously with the a-points the planimetric co-ordinates x and y of the b- and c-points of the five photogrammetric measurements were transformed in linear conformal manner into the system of the mean values of the terrestrial measurements of the a-points (see item 2.1).

Together with the fitting in of the heights z of the a-points into the corresponding mean values of the terrestrial measurements, also the heights of the b- and c-points were displaced in parallel direction (see item 2.1).

Item 2.3 Determination of the photogrammetric d- and e-lines
The computation of the photogrammetric co-ordinates of the d- and e-points corresponds to that for the a-, b- and c-points given under items 2.1 and 2.2. The further computations for the d- and e-lines correspond to those given under item 1.3.

Item 3. Photogrammetric measurements of the same Restitution Centre
In some Restitution Centres, two observers had restituted independently one (or 2) model(s) of each flight. Of these, only one measurement was used for the

computation under item 2.

Then, we transformed, also in linear conformal manner, the photogrammetrically measured planimetric co-ordinates of all points of the second measurements by means of the co-ordinates of the a-points into the terrestrial system. The heights were converted by means of a parallel displacement. As values of comparison served the mean values of all five terrestrial measurements according to item 1.1.

Items 4 and 5 of the computing programme deal with further comparisons of the photogrammetric measurements with the terrestrial measurements. These error computations will only be dealt with in chapter 4.

Originally the programme also included the computation of c'-points, i.e. roof corners as intersections of two roof eaves but the test field did not dispose of a sufficient number of such points.

The programming work was carried out by the Netherlands Cadastral Survey at Apeldoorn. A Philips P 880 computer was available there.

The tasks comprised:

- Locating and correcting (or eliminating) gross errors;
- Computation of the final co-ordinates;
- Determination of the accuracy of the measurements (see chapter 4).

3.2 Processing of the Results of the Terrestrial Measurements

3.2.1 Computation of the Terrestrial Co-ordinates for each Station

With the aid of the computing programme of the University of Technology at Delft, the measured polar co-ordinates were converted into orthogonal co-ordinates x, y. At the same time the heights z were computed with the aid of the tangents of the vertical angles. Before the transformation the input data were checked and, if necessary or possible, corrected. After the transformation the co-ordinates of all points measured twice by each survey team, i.e. the co-ordinates obtained from the two series as well as the co-ordinates for each of the two end points of a roof eave were averaged. In case several setup points were required for one station, the co-ordinates x, y of the system of the second setup point were transformed in linear conformal manner - without change of scale - into the system of the first setup point by means of the common a-points and the tie points meant for this purpose (see chapter 2.2.2). The heights z were displaced only in parallel direction. This way the co-ordinates of the a-, b-, c- and d-points were known in a local system, with the first setup point as co-ordinate origin. These local systems served as basis for the subsequent computations.

Although for each station the planimetric co-ordinates of the different local systems indeed were transformed into a uniform system, the computing process was slightly changed with respect to item 1.1 of the computing programme considering that not every survey team had measured all a-points. By means of the a-points the co-ordinates of the survey teams 2 - 5 were transformed one after the other into the system of the first survey team. This means that we disposed for each a-point of five co-ordinate triples in o n e co-ordinate system. Subsequently

these co-ordinates were averaged and the co-ordinates of the five survey teams were once more transformed in linear conformal manner into the system of these mean values. Averaging and transformation were repeated until there were no more significant changes.

With the last transformation parameters the co-ordinates of the b-, c- and d-points were then converted into the system of the a-points. Subsequently these co-ordinates were averaged as well. The arithmetic mean values of the a-, b- and c-points are the final terrestrial co-ordinates (see items 1.1 and 1.2 of the computing programme).

In the case of the d-points these mean values correspond to the centres of gravity obtained from the maximally five measurements at the beginning and at the end of a d-straight. By menas of these two centres of gravity the final terrestrial d-straight is determined (see item 1.3 of the computing programme). For the detection of gross errors (see chapter 3.22) and for the error computations (see 4.1) all d-points measured by the five field parties were for each roof eave transformed into a new orthogonal system formed by the d-straight and a plane perpendicular to the straight at the beginning (left) and at the end (right) centre of gravity respectively. In this new system the deviations of the single d-points from the d-straight were determined.

3.2.2 Gross Errors of the Terrestrial Measurements

The Pilot Centre experienced that for such extensive tests the detection and, in particular, the finding out of the source of gross errors and - if possible - their correction takes a great deal of time. In the present case, where great importance is attached to a perfect terrestrial basis of comparison, therefore as many as five terrestrial measurements were carried out as a matter of precaution. Moreover, it was to be assured that in the processing of these measurements no measuring results were discarded unnecessarily. For this reason different tolerances were included in the computing process, depending on the tolerances of each preceding computational step as well as on the kind of point.

As to the terrestrial measurements, we can describe the standard deviation σ_t of a single measurement as follows:

$$\sigma_t^2 = \sigma_{instr}^2 + \sigma_{ident}^2 + \sigma_{abl}^2$$

where

σ_{instr} = standard deviation caused by the instrument,

σ_{ident} = standard deviation of the identification,

σ_{abl} = standard deviation of the plumbing (only for c- and d-points).

On the basis of the experiences and test measurements made, for these standard deviations the following values were assumed:

σ_{instr} = 3.0 cm;

σ_{ident} = 2.0 cm;

σ_{abl} = 2.5 cm.

Considering that a difference of about 6σ between single observations is statistically still justifiable, for the detection of gross errors of the differences between the two series of one field party the following tolerances were used:

- for the planimetric co-ordinates x and y: 30 cm
- for the heights z : 40 cm (see table 4).

While the identification and plumbing errors play no part for the a-points, the plumbing errors are important for the b-points; nevertheless, we chose for these types of points the same tolerances as we did for the c- and d-points. As far as the heights are concerned we expected a larger additional identification error as well as an influence of the vertical angle measurements (tangents of the vertical angles).

For the two series along the roof lines the d-points could in most cases not be identified unambiguously. Therefore the tolerances indicated in table 4 only apply to the transversal deviation q = y. For the deviations in the direction of the roof ($\bar{x}$-axis) a tolerance of 4 m was introduced for identity control. As to the deviations of the results obtained by the individual field parties from the total mean, we have to do, on the one side, with mean values of two series and, on the other side, with the mean of the results obtained by five field parties. This means that here the tolerances should be about half as large as in the preceding instances. We now considered, however, that for the a-points the identification and plumbing errors are of no importance and took for the planimetric co-ordinates x, y and the heights z the following tolerances into account:

- a-points : 10 cm
- b-, c- and d-points : 15 cm

After the correction of the gross errors, the errors of the a-points remained even within a tolerance of 5 cm.

On the whole - apart from the auxiliary points and the plumbed roof points, which were eliminated - the Pilot Centre examined 3410 point measurements (means obtained from two series). During the first run 2814 measurements stayed within the tolerances which does not mean, however, that all of the remaining 596 measurements were erroneous; if an a-point had not been measured correctly, the appertaining b-, c- and d-points could neither be computed. For this reason the co-ordinates of two stations could not be computed at all which reduced the number of stations to 69. Altogether 414 errors could be detected and corrected so that in the end 182 point measurements or 5.4% were lost. The reasons for faulty measurements or faulty data were:

- Horizontal angle measurements 24%
- Vertical angle measurements 39%
- Point confusions 20%
- Distance measurements 11%
- Unknown (single measurements) 6%

How the computed co-ordinates of the 3228 point measurements are distributed over the different types of points is shown in the following table:

Type of point	Number of points	Number of point measurements (Mean of two series)
a	262	1 250
b	23	114
c	81	390
d	300	1 474
Total	665	3 228

On account of the reduced number of observations, five independently measured co-ordinates (five field parties) are no longer available for every point, however, the deviations are small.

3.3 Processing of the Results of the Photogrammetric Measurements

3.3.1 Computation of the Photogrammetric Co-ordinates for Every Station

Ten different Restitution Centres carried out the measurements. For the main test i.e. for the restitutions 1 - 4 (first operator) every station was, as a rule, measured by five Centres (see table 3). This means that maximally 20 co-ordinate sets exist for every station. This does not apply to the restitutions 5 - 8 though (second observer); here maximally 8 and 19 sets of co-ordinates respectively are available for one station. We left, however, unconsidered that at a photo scale of 1:6000 a number of stations is found on strip 1 as well as on strip 2.

To facilitate the work of the Pilot Centre, the Commission decided that the Restitution Centres were to carry out so much of the computational work that the Pilot Centre could be provided with co-ordinates that are approximately national co-ordinates. This measure offered the advantage that subsequently to its own measurements every Restitution Centre could also use its own computing programmes and that - if necessary - gross errors could be corrected by the Restitution Centres themselves. Here, too, special rules had to be observed, namely:

1) If the Restitution Centres use stereocomparators, they must subsequently compute model co-ordinates. The residual parallaxes must be indicated.
2) By means of given control points the Restitution Centres are to transform the model co-ordinates in linear conformal manner into the terrestrial system. For the a-, b- and c-points the two series of one operator must be averaged first. For the a-, b- and c-points the mean differences and the standard errors of the mean respectively are to be indicated in "millimetre in the terrain" model by model (compare measuring accoracy M and fitting accuracy E of the test Reichenbach).
3) The results of the computation are to be furnished to the Pilot Centre as hard copy and on punched tapes or punched cards. Punched cards are preferred. The results should be listed in the co-ordinate list per station. Per station, the a-, b-, c-, d- and e-points should follow one another by groups in ascending

numerical order. The sequence of the data is: point number, x, y, z. It is assumed that the results have already been cleaned by the Restitution Centres, i.e. that all data which are not valid have been eliminated.

4) A report should indicate how the results were obtained and what measurements were eliminated. The report is also to include transformation constants, lists of errors, time required and the like.

Subsequently to the measurements the model co-ordinates were transformed into the terrestrial Dordrecht co-ordinate system by means of a plane or spatial similarity transformation (Helmert transformation). The residuals in the control points were often used to compute a fitting accuracy. But since these computations were not carried out uniformly, a comparison of results does not reveal much.

The internal accuracy of the photogrammetric measurements will be investigated in a later chapter (see chapter 4.2). The Pilot Centre received from every Restitution Centre the transformed co-ordinates punched on cards and arranged by stations and types of points. Apart from the a-, b-, c- and d-points the Restitution Centres also measured the e-points, i.e. the points on the roof ridges.

The computational work of the Pilot Centre comprised the following working steps (see item 2 of the computing programme):

- In case the Restitution Centres had not averaged the results of the two series of one model, these results were first averaged.
- The planimetric co-ordinates of the a-points of several stations had not been determined terrestrially in a uniform system but each station had its own local system. Therefore the computing programme was modified and the maximally five photogrammetrically determined co-ordinates were averaged. For every station and every restitution the averaged terrestrial co-ordinates (i.e. the real co-ordinates of comparison) were, with the aid of the a-points - without change of the scale - transformed by linear conformal transformation into the photogrammetric system, i.e. into a system whose x-axis runs parallel to the flight axes.
- The heights were displaced only in parallel direction into the terrestrial system (mean of the a-points).
- For the e-lines no terrestrial measurements of comparison are available. For this reason, after the transformation, only the co-ordinates obtained from the five restitutions were averaged. These mean values correspond to the centres of gravity at the beginning or end of an e-line, and define the final photogrammetric e-line.

For the detection of gross errors (see chapter 3.3.2) and for the error computations (see chapter 4.2) all e-points measured by the maximally five Restitution Centres for each roof ridge were transformed into a new orthogonal system formed by the final e-line and a plane vertical to it at the beginning (left) and at the end (right) centre of gravity respectively. In this system the deviations of the single e-points from the final e-line were determined.

All computations mentioned apply to the measurements of the first as well as to those of the second operator.

3.3.2 Gross Errors of the Photogrammetric Measurements

The Restitution Centres involved had done their best to measure as many of the indicated points as possible. Due to various reasons not all of the Centres were in the position to have the measurements repeated by a second operator. Therefore the number of the theoretically possible (planned) 29 040 point measurements (means of two series) was reduced to 25 840 measurements. The Pilot Centre, however, had only 23 450 measurements at its disposal. The reasons for the loss of another 2390 measurements (about 9%) must, according to the records of the Restitution Centres, primarily be attributed to:

- Identification difficulties and
- large differences between the first and second series.

What criteria (tolerances) were used by the single Restitution Centres is unfortunately not clear. Before the transformation the Pilot Centre had to reject another 415 measurements for the following reasons:

- The co-ordinates of some photogrammetrically measured stations could not be transformed because the number of corresponding a-points did not suffice. This meant a loss of 105 measurements.
- Several Restitution Centres had measured points which lacked terrestrial co-ordinates. Because of this another 310 measurements were lost.

On the whole 23 035 photogrammetric measurements could be transformed into the terrestrial co-ordinate system. To avoid gross errors, for these computations different tolerance limits were incorporated in the computing process, depending on the photo scale as well as on the type of point.

As a result of test measurements for each restitution provisional standard errors were determined, and the greatest values in each of both scales were multiplied by 4 and rounded off. Gross errors in the a-points were corrected or eliminated and then the transformations were repeated. This way the other points of the stations did not get lost. Another check for gross errors resulted in the tolerance limits indicated in table 4. Table 5 shows the point measurements which were not used on account of exceeded tolerances. The measurements of the two operators were compiled and the differences between the terrestrially and photogrammetrically determined co-ordinates were, according to their size, arranged in groups, separated according to restitutions and types of points. The interval width depended on the tolerance limit. An analysis disclosed that the numerous exceeded tolerances for the d-points (1:3500 scale) resulted primarily from four model measurements. For one model of restitution 2, Restitution Centre 0 and for another model of restitution 8, Restitution Centre 5, all points (except the a-points) had to be rejected. In these models probably the height scale should be larger by a factor two. As the Restitution Centres - contrary to the rules - had supplied only tranformed co-ordinates, the Pilot Centre was not in a position to find out the exact reason for this.

Since all control points have about the same height it was neither possible to detect such an error during the absolute orientation. A model of restitution 2, Restitution Centre 5 and another model of restitution 8, Restitution Centre 5 also resulted in high point losses due to exceeded tolerances in z. The reason for this may also be an error in the height scale. These 4 of the altogether 118 model measurements at 1:3500 scale contained 130 of the altogether 281 exceeded tolerances for the d-points. The same models also contained 4 exceeded tolerances for the b-points and 28 for the c-points. The remaining values exceeding the tolerances are about equally large for both scales and amount to approx. 2%. They are rather regularly distributed over the different restitutions and Restitution Centres.

4. Accuracy of the Measurements (Error Computations)

4.1 Accuracy of the Co-ordinates Determined Terrestrially

For the determination of the standard co-ordinate errors (standard deviations) the computing programme includes - in condensed form - the following computations:

Item 1.1 Accuracy of the terrestrially determined co-ordinates of the a-points

From all values v_x and v_y of one station, i.e. from the differences between the planimetric co-ordinates of each single measurement and the co-ordinate means of the maximally five measurements, we obtain the standard co-ordinate error m_{ka} of a measurement from

$$m_{ka} = \sqrt{\frac{[v_x^2] + [v_y^2]}{(2n_p - 3)\ (i-1)}} \tag{41.01}$$

Here

n_p = number of the a-points of the station.

$i = 5$ = number of the measurements.

The standard error for all stations must be computed accordingly.

For the standard height error m_{za} applies accordingly:

$$m_{za} = \sqrt{\frac{[v_z^2]}{(n_p - 1)\ (i-1)}} \tag{41.02}$$

Here

$$dz_{n,i} = z_n - z_{n,i} \tag{41.03}$$

and

$$v_{z_{n,i}} = dz_{n,i} - \frac{[dz_{n,i}]}{n} \tag{41.04}$$

In this case, too, a mean value was computed for all stations.

On account of the irregular number of a-points per station, m_{ka} and m_{za} were computed from the v_x, v_y and v_z of the altogether 261 a-points of all 69 stations. This means that on an average there are 3.8 a-points per station.

Item 1.2 Accuracy of the terrestrially determined co-ordinates of the b- and c-points

Considering that the number of the b- and c-points of each station is small and that the single points were probably measured with varying accuracy it is recommended to compile the errors of all points. From all values v_x and v_y we obtain the standard co-ordinate errors m_{kb} and m_{kc} respectively of planimetry from

$$m_{kb} \text{ and } m_{kc} \text{ resp.} = \sqrt{\frac{[v_x^2] + [v_y^2]}{2N_p(i-1)}} \tag{41.05}$$

Here

N_p = number of all b- and c-points respectively.

The influence of the errors in the a-points in this case is left unconsidered.

Note: Originally, the computing programme was to compute the standard errors for each point and to compile the errors and the $[v^2]$ respectively of all points only at the end in order to be able to better analyse the reasons for the errors and the components of errors.

For the height applies accordingly

$$m_{zb} \text{ and } m_{zc} \text{ resp.} = \sqrt{\frac{[v_z^2]}{N_p\ (i-1)}} \tag{41.06}$$

Item 1.3 Accuracy of the terrestrially determined co-ordinates of the d-points

According to chapter 3.1 item 1.3 the co-ordinates of the maximally five d-points were averaged at the beginning of each d-line (left) and at the end of each d-line (right). By means of these two centres of gravity the final terrestrial d-line is determined. All d-points measured by the five field parties were for each roof eave transformed into a new orthogonal system formed by the final d-line and a plane perpendicular to it in the beginning (left) or in the end (right) centre of gravity. Thus the horizontal deviations v_y and the vertical deviations v_z of the single d-points of the d-line are determined (vide chapter 3.2.1).

For the same reasons as for the b- and c-points, the errors of all points were compiled. From the values v_y we obtained the standard co-ordinate error m_{kd} of planimetry from

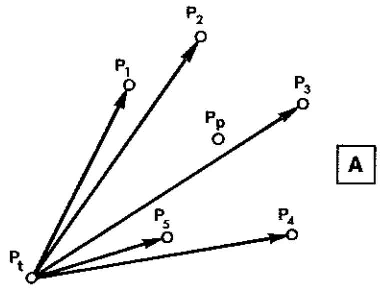
$$m_{kd} = \sqrt{\frac{[v_y^2]}{N_p\ (i-1)}} \tag{41.07}$$

Here

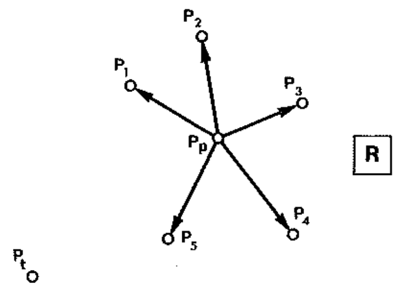
N_p = number of all points.

For the standard co-ordinate error m_{zd}, accordingly equation (41.06) applies.

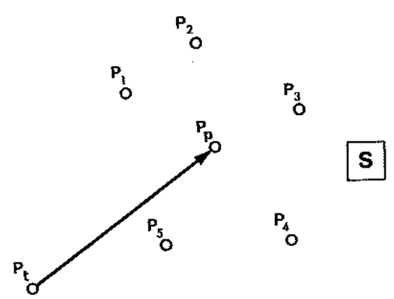
The results of the computations are shown in table 6. Considering that some points were not measured by all $i = 5$ field parties, in the compilation of the errors for the different types of points the value $N_p \cdot i$ was replaced by the number N_M .



a) absolute errors
Δ_q = co-ordinate differences between P_t and P_i



b) relative errors from the deviations with respect to the co-ordinate means of all restitutions
Δ'_q = co-ordinate differences between P_p and P_i



c) systematic deviations from the co-ordinate means of all restitutions
Δq_s = co-ordinate differences between P_t and P_p

Figure 9 — Explanatory notes regarding the standard errors according to the computing programme

Here is:

P_t	terrestrially determined point, mean of $i = 5$ measurements (centre of gravity)
$P_1, P_2 \ldots P_i$	photogrammetrically determined points for different restitutions of a flight ($i = 5$)
P_p	centre of gravity of $P_1, P_2 \ldots P_i$. Mean of $1 = 5$, partially of $i = 10$ restitutions.

of the measurements. In conclusion, the standard errors of all b-, c- and d-points were averaged: g-points (vide also [4]).

Table 7 shows the distribution of the v-values separately for co-ordinates and types of points. The given tolerances had, of course, been observed. Nevertheless some extreme values, larger than the 6-fold value of the standard error, attract notice. Approximately 1.5% of all deviations are above the 3-fold value of the standard error. The v-values in the screened area are to be considered as "gross" errors with an error probability of 0.1%, or, in other words, in the case of 1000 observations only one observation may lie within the screened area if the errors are distributed normally. This probability of 0.001 corresponds to an error limit of the 3.29-fold of the standard error.

4.2 Accuracy of the Co-ordinates Determined Photogrammetrically

Part of the accuracy computations had to be carried out by the Restitution Centres (vide chapter 3.3.1), namely the computations of the "inner" accuracy of their own photogrammetric measurements. The computation programme further included the computation of the absolute accuracy from the differences between the transformed photogrammetric co-ordinates and the corresponding terrestrial co-ordinates of comparison. In order to separate the irregular photogrammetric errors from the systematic part of the errors, the absolute errors are splitted up into a systematic part and a relative part (vide [5]). The systematic part corresponds to the difference between the mean of the photogrammetric co-ordinates of a point and the corresponding terrestrial co-ordinates of comparison (mean value of the maximally i = 5 terrestrial measurements); the relative part is obtained from the deviations of the photogrammetric single measurements of a point from the corresponding mean value (see fig. 9). Nearly all of these errors include to some extent the errors of the terrestrial co-ordinates of comparison.

Photos at a large scale furnish more accurate results than photos at a small scale. In order to render a better comparison possible, we give the accuracy figures partly in "cm in the terrain" as well as in "µm in the image". The choice of the restitution instrument was left to the Restitution Centres because it was not intended to investigate the accuracy of different restitution instruments. We neither considered the ratio between model scale and photo scale. For computational reasons we chose as smallest unit 0.1 µm and 0.1 cm respectively. This way it became possible to use the standard errors for further computations and for the analysis without running the risk that the results are too much falsified on account of the rounding-off errors. For the d- and e-points we can only calculate mean transversal deviations $m_q = m_y$ from a straight line. For this reason we also compiled for the other types of points the standard errors m_x and m_y to a co-ordinate error m_k so that all planimetric errors are directly comparable with each other.

4.2.1 Measuring Accuracy M

From the differences d_x, d_y and d_z between series 1 and series 2 the standard errors m_x, m_y and m_z (standard co-ordinate errors of the mean of two measurements) are to be computed - separately for the a-, b- and c-points, viz:

$$m_q = \sqrt{\frac{[d_q^2]}{4\ N_P}} \tag{42.11}$$

Here:

q = x, y, z

N_P = number of the points (differences).

The Restitution Centres calculated these standard errors for each restitution separately. Table 8 gives the results in "cm in the terrain". Instead of the standard errors m_x and m_y we have indicated the standard co-ordinate errors m_k. Unfortunately some of the Restitution Centres did not calculate the required errors separately for the different types of points. As far as possible the Pilot Centre carried out the additional computations. Since Restitution Centre 3 carried out comparator measurements, there are no m_z values. We have summarized the results of table 8. Table 9 gives the average values for each restitution in "cm in the terrain" as well as in "μm in the image". For the restitutions 1 - 4, N_P applies only the planimetric co-ordinates m_k. Unfortunately, Restitution Centre 0 did not submit any results.

4.2.2 Absolute Accuracy A

For the comparison of the photogrammetrically determined co-ordinates with the terrestrial co-ordinates, the mean values obtained from the five terrestrial measurements were used on principle. In all the following errors of the photogrammetrically determined co-ordinates a part of the errors of the terrestrial measurements is included.

Item 2.1 Absolute accuracy of the photogrammetric co-ordinates of the a-points

From the total number of the values Δx and Δy of one station, i.e. from the differences between the photogrammetrically determined planimetric co-ordinates (single measurement) and the corresponding terrestrial mean values, the standard co-ordinate deviation $m_{\Delta ka}$ of a single photogrammetric measurement can be found from:

$$m_{\Delta ka} = \sqrt{\frac{[\Delta x^2] + [\Delta y^2]}{(2n_P - 3) \cdot i}} \tag{42.21}$$

Here:

n_P = number of the a-points of the station

i = 5 = number of the measurements.

The standard deviation for all stations is to be calculated accordingly.

For the standard height deviations $m_{\Delta za}$ we have:

$$m_{\Delta za} = \sqrt{\frac{[\Delta z^2]}{(n_P - 1) \cdot i}} \tag{42.22}$$

Item 2.2 Absolute accuracy of the photogrammetric co-ordinates of the b- and c-points

For the same reasons as for the terrestrial measurements here, too, the errors of all points are compiled. Again we compute for each point the differences Δx and Δy and thus obtain the standard co-ordinate deviations (planimetry) from:

$$m_{\Delta kb} \text{ and } m_{\Delta kc} \text{ resp.} = \sqrt{\frac{[\Delta x^2] + [\Delta y^2]}{2\ N_P \cdot i}} \tag{42.23}$$

For the standard height deviations, we have accordingly

$$m_{\Delta zb} \text{ and } m_{\Delta zc} \text{ resp.} = \sqrt{\frac{[\Delta z^2]}{N_P \cdot i}} \tag{42.24}$$

Item 2.3 Absolute accuracy of the photogrammetric co-ordinates of the d-points

In the same way the terrestrially determined co-ordinates were transformed we also transformed the photogrammetrically determined co-ordinates of the d-points into the new orthogonal system described in chapter 4.1 item 1.3. This means that we do not compare lined with lines but horizontal transversal deviations Δy and vertical deviations Δz of the photogrammetrically determined d-points from the terrestrially determined d-line.

From all the values Δy results the standard transversal deviation $m_{\Delta kd}$ from:

$$m_{\Delta kd} = \sqrt{\frac{[\Delta y^2]}{N_P \cdot i}} \tag{42.25}$$

Again N_P = number of all d-points.

For the standard height deviation $m_{\Delta zd}$, accordingly equation (42.24) applies.

The standard deviations were calculated separately for each restitution and for each Restitution Centre. Because the Pilot Centre had transformed - contrary to the computing programme - the averaged terrestrial co-ordinates into the photogrammetric system, the original denominator $2(n_P - 2) \cdot i$ of equation (42.21) was changed accordingly (see also chapter 3.3.1). Table 10 gives the results in "cm in the terrain". Again we have summarized these results. Table 11 contains the average values for each restitution in "cm in the terrain" as well as in "μm in the image" [1].

Because some points were not measured by all i = 5 Restitution Centres, in the compilation of the deviations for the b-, c- and d-points the value $N_P \cdot i$ was again replaced by the number of the measurements N_M.

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[1] The standard errors in "μm in the image" for the d- and e-points given in the tables 3, 4 and 5 of the report [3]are co-ordinate errors m_k.

4.2.3 Relative Accuracy R

To determine the deviations of the co-ordinates of the a-points of repeated restitutions, first the transformed planimetric co-ordinates x and y of the i = 5 photogrammetric measurements of each point are averaged (vide chapter 3.1 item 2.1). From the deviations $\Delta x'$ and $\Delta y'$ of the single values from the corresponding mean value we then obtain for every single point the standard deviation:

$$m'_{\Delta k} = \sqrt{\frac{[\Delta x'^2] + [\Delta y'^2]}{2(i-1)}} \qquad (42.31)$$

Accordingly applies to the heights:

$$m'_{\Delta z} = \sqrt{\frac{[\Delta z'^2]}{i-1}} \qquad (42.32)$$

If we now combine the $[\Delta'\Delta']$ of all stations of one restitution, the number of the redundant observations still stands in the denominator but instead of 2(i - 1) it is now $(N_M - N_P)$. The computation of the relative accuracy of the b- and c-points is done in the same manner and according to the same formulae. For the d-points the horizontal transversal deviations Δy and the vertical deviations Δz from the terrestrially determined d-line were used instead of the transformed photogrammetric co-ordinates x, y and z in the system of the a-points (see chapter 4.2.2 item 2.3). In this case:

$$m'_{ka} = \sqrt{\frac{[\Delta y'^2]}{i-1}} \qquad (42.33)$$

To the heights, accordingly equation (42.32) applies.

According to chapter 3.1 item 1.3, the photogrammetric co-ordinates each of the maximally five e-points at the beginning of each e-line (left) and at the end of each e-line (right) were averaged. By means of these two centres of gravity the final photogrammetric e-line is determined. All e-points measured by the five Restitution Centres were for each roof ridge transformed into a new orthogonal system which is formed by the final e-line and a plane perpendicular to it in the beginning (left) or in the end (right) centre of gravity. Thus the horizontal deviations v'_y and the vertical deviations v'_z of the single e-points from the e-line are determined (vide chapter 3.3.1). These deviations v'_y and v'_z are identical with the values $\Delta y'$ and $\Delta z'$ looked for. To the computation of the standard relative errors of the e-points apply accordingly the equations (42.33) and (42.32).

Contrary to the computing programme, the Pilot Centre has not always combined the five repeated photogrammetric measurements. This is because some of the stations are located within the overlapping zone of the two strips of one flight. In these cases the altogether 2 x 5 = 10 measurements were therefore combined to a mean value. This held true for the restitutions 1, 3, 2 and 4 with 28, 41, 5 and 13 stations respectively. Table 12 contains the average values for each restitution in "cm in the terrain" as well as in "µm in the image".

4.2.4 Systematic Deviations S

To determine systematic deviations of the photogrammetric co-ordinates of the a-points, for every a-point the differences

$$\Delta x_s = \bar{x}_p - \bar{x}_t \text{ and } \Delta y_s = \bar{y}_p - \bar{y}_t \text{ resp.} \qquad (42.41)$$

between the mean values of the maximally five (and 10 respectively) photogrammetric measurements and the corresponding terrestrial co-ordinates of comparison are formed. From this results the mean square value for all points

$$m_{\Delta ks} = \sqrt{\frac{[\Delta x_s^2] + [\Delta y_s^2]}{2\,N_P}} \qquad (42.42)$$

For the heights we have accordingly:

$$m_{\Delta zs} = \sqrt{\frac{[\Delta z_s^2]}{N_P}} \qquad (42.43)$$

The computation of the systematic deviations of the photogrammetric co-ordinates of the b- and c-points was carried out in the same manner and according to the same formulae. For the d-points the mean values of the horizontal transversal deviations Δy and the vertical deviations Δz are identical with the systematic deviations Δy_s and Δz_s. In this case

$$m_{\Delta ks} = \sqrt{\frac{[\Delta y_s^2]}{N_P}} \qquad (42.44)$$

To the heights, accordingly equation (42.43) applies.

As a check, the original computing programme included the computation of the values Δx_s, Δy_s from the differences Δx and Δy between the photogrammetrically determined planimetric co-ordinates of each single measurement and the corresponding terrestrial mean values (see chapter 4.2.2) because

$$\Delta x_s = \frac{[\Delta x]}{i} \text{ and } \Delta y_s = \frac{[\Delta y]}{i} \text{ resp.} \qquad (42.45)$$

Eliminating the constant parts Δx_s and Δy_s from the values Δx and Δy, we then obtain for the computation of the relative accuracy (vide chapter 4.2.3):

$$\Delta x' = \Delta x - \Delta x_s \text{ and } \Delta y' = \Delta y - \Delta y_s \text{ resp.} \qquad (42.46)$$

To the heights corresponding formulae apply.

This check is not applicable to the e-points. The above procedure corresponds, by the way, approximately to the procedure applied to the d- and e-points. For the d-points the mean values $\bar{y}_p$ and $\bar{z}_p$ of the photogrammetric co-ordinates are equal to the systematic deviations Δy_s and Δz_s. For the e-points we referred the horizontal transversal deviations v'_y and the vertical deviations v'_z to the photogrammetrically determined straights. This means that $\Delta y_s = \Delta z_s = 0$ and thus $\Delta y = \Delta y'$ and $\Delta z = \Delta z'$ respectively.

For the reasons indicated in chapter 4.1 item 1.2 (e.g. low number of points per station) in this case, too, the errors of all points were immediately combined. Table 13 contains the average values for each restitution in "cm in the terrain" as well as in "μm in the image".

From the basic equation (42.46) it follows that a relation exists between the absolute accuracy m_A, the standard systematic deviations m_S and the relative accuracy m_R (see [5]), viz:

for the a-points

planimetry:
$$\left(1 - \frac{3\ N_{St}}{2\ N_P}\right) \cdot m_A^2 = \left(1 - \frac{1}{i}\right) \cdot m_R^2 + m_S^2 \qquad (42.47)$$

heights:
$$\left(1 - \frac{N_{St}}{N_P}\right) \cdot m_A^2 = \left(1 - \frac{1}{i}\right) \cdot m_R^2 + m_S^2 \qquad (42.48)$$

and for the b-, c- and d-points:

planimetry and height:
$$m_A^2 = \left(1 - \frac{1}{i}\right) \cdot m_R^2 + m_S^2 \qquad (42.49)$$

Here N_{St} = number of the stations.

These formulae hold only for i = const. Because of the omissions and rejections of points and because of the fact that, in the computation of the standard relative errors, the results of two strips had in part been combined, in our case $i \neq$ const. As an approximation, i can be replaced by the ratio $N_M : N_P$.

Some computations of the original computing programme were modified or not carried out at all, because the measurements sometimes lacked completeness or because some measurements had been eliminated ($i \neq 5$), viz.:

- The computation of standard errors for every single station is missing. In the processing of the terrestrial as well as of the photogrammetric measurements, the results of all stations have always been combined. This rendered the search for possible residual gross errors more difficult. The number of the points per station, however, often was too small; this applied in particular to the b-points.
- The computation of so-called c'-points, i.e. of intersection points of two eaves belonging to one roof is missing, because there were hardly any such points.
- A comparison of the accuracy of the measurements of the 1st operator with those of the 2nd operator can only be made for the absolute accuracy. A direct comparison of both photogrammetric measurements was dropped. Anyway, the 2nd operators, if at all, only restituted part of the models.
- The computing programme included two independent computations of the same errors as computing check. These checks are missing.

- There were some formal changes of the programme that were of no consequence, i.e. whether the systematic deviations were computed by means of the mean values of the photogrammetric measurements or by means of the co-ordinate differences Δx, Δy and Δz. Further, the more elegant treatment of the d- and e-points and the d- and e-lines by the Pilot Centre agrees in contents with the proposed computing programme.

5. Comparison of Different Standard Errors

Introduction

The tables in chapter 4 contain already the solution of some problems of the test programme. For the analysis we combined the results of the photogrammetric measurements according to different parameters, e.g. for the scale 1:6000 the results of the restitutions 1 and 3, etc. We call these combinations in short restitutions 13, etc. Again we calculated the standard errors up to 0.1 μm and 0.1 cm respectively. When comparing the standard errors, it should be noted that in the fundamental test the number of single measurements per strip is about equal but that the number of points per point type differs. It seemed useful to combine the results obtained for the b-, c-, d- and e-points, i.e. for all non-signalised building points together (g-points). For this reason we additionally computed the standard errors for the b-, c-, d- and e-points together. In these cases we considered the single standard errors for these four point types as not being of equal weight in order to avoid assigning an overweight, e.g. to the few b-points. To make the different accuracy values for the non-signalised points more distinct, we referred the four standard errors to the errors of the c-points because the number of the c-points is larger than the number of the b-points. In individual sections we deal - in the sequence of the different parameters, viz. point type, photo scale, operator and position of the sun - first with the standard co-ordinate errors m_k in μm and then with the standard height errors m_z in μm. The question on the significance of the accuracy differences, in particular with respect to the absolute accuracy, cannot be answered easily since the number of the degrees of freedom cannot be determined unambiguously. Based on rough computations we assume that differences in accuracy up to 10% are not significant with a likelihood of 95%. For daily practice, however, such differences can already be of importance. Therefore the ratio figures were rounded off to 5%, i.e. to 0.05.

5.1 Comparison of the Standard Errors of the Terrestrial Measurements

In table 6 we have compiled the standard errors of the terrestrial measurements. In particular, we find:

- The standard co-ordinate errors m_k of the four point types are in the proportion of 0.75 : 1.70 : 1.00 : 1.25. The standard error of the a-points amounts to 1.3 cm, the standard error of the b-, c- and d-points amounts, however, to 2.1 cm. According to this the ratio of the standard planimetric error m_k of the signalised points (a-points) to the errors of the non-signalised building points (g-points) is about 1.00 : 1.60.
- The standard height errors m_z of the four point types are in the proportion of 0.70 : 2.40 : 1.00 : 1.40. Striking is the large error of the b-points, in

particular compared to the small error of the c-points. The standard error of the a-points amounts to 1.3 cm, that of the b-, c- and d-points amounts, how- ever, to 2.7 cm. According to this the ratio of the standard height error m_z of the signalised points (a-points) to the error of the non-signalised building points (g-points) is about 1.00 : 2.10.

- Since the standard errors m_k and m_z of the a-points are equally large, the four errors, namely the errors m_k of the a- and g-points as well as the errors m_z of the a- and g-points, are in the proportion of about 1.0 : 1.5 : 1.0 : 2.0.

5.2 Comparison of the Standard Errors of the Photogrammetric Measurements

5.2.1 Measuring Accuracy M

In table 9 we have compiled the standard measuring errors for the single restitu- tions. These values represent the highest attainable accuracy which can be reached in our later investigations. We now regroup the results according to the different variables, separately for the group of the 1st operators and the group of the 2nd operators (table 14). For the sake of completeness we finally also combine the results obtained by both the operator groups. However, in comparing the results we confine ourselves to the fundamental test, i.e. to the first operator group.

In particular, we find:

- The standard measuring error m_k of the three point types in "μm in the image" are for the fundamental test in the proportion of 0.60 : 1.55 : 1.00. The stand- ard error of the a-points m_k = 3.0 μm and that of the b- and c-points m_k = 5.2 μm. According to this the ratio of the standard planimetric error of the signalised points (a-points) to that of the non-signalised points (g-points) is about 1.00 : 1.75.
- For the scale 1:3500 the standard measuring error m_k of the a-points in "μm in the image" is approximately 15% smaller than for the scale 1:6000. The corre- sponding errors of the non-signalised points are for both scales equally large.
- For the 2nd operator group the standard measuring errors m_k of the a-points are 15% larger, those of the non-signalised points 20% larger than the correspond- ing errors of the 1st operator group.
- For the morning and afternoon flights the standard measuring errors of the a- points as well as those of the non-signalised points are practically equal.
- The standard measuring errors of the heights m_z of the three point types are for the fundamental test in the proportion of 0.75 : 0.90 : 1.00. The standard height error of the a-points m_z = 8.6 μm and that of the b- and c-points m_z = 11.0 μm. According to this the ratio of the standard height error of the signalised points to that of the non-signalised points is about 100 : 1.30.
- For the scale 1:3500 the standard height error m_z of the a-points in "μm in the image" is about 10% smaller than for the scale 1:6000. The errors of the non- signalised points are practically equal for both scales.
- For the 1st and 2nd operator group the standard height errors m_z of the a-points are equally large. The standard errors m_z of the non-signalised points for the 2nd operator group are 25% larger than for the 1st operator group.

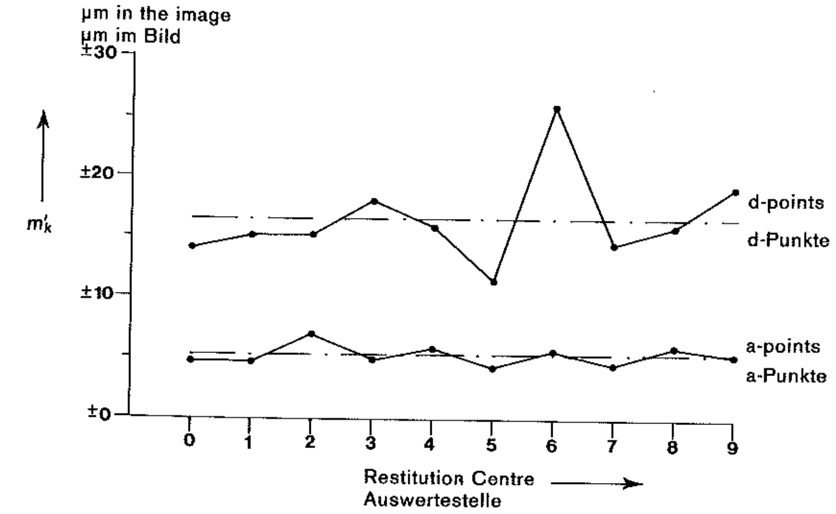
- For the morning and afternoon flights the standard height errors m_z of the a- points are equally large. The standard height errors of the non-signalised points are for the afternoon flights 10% smaller than for the morning flights.

5.2.2 Absolute Accuracy A

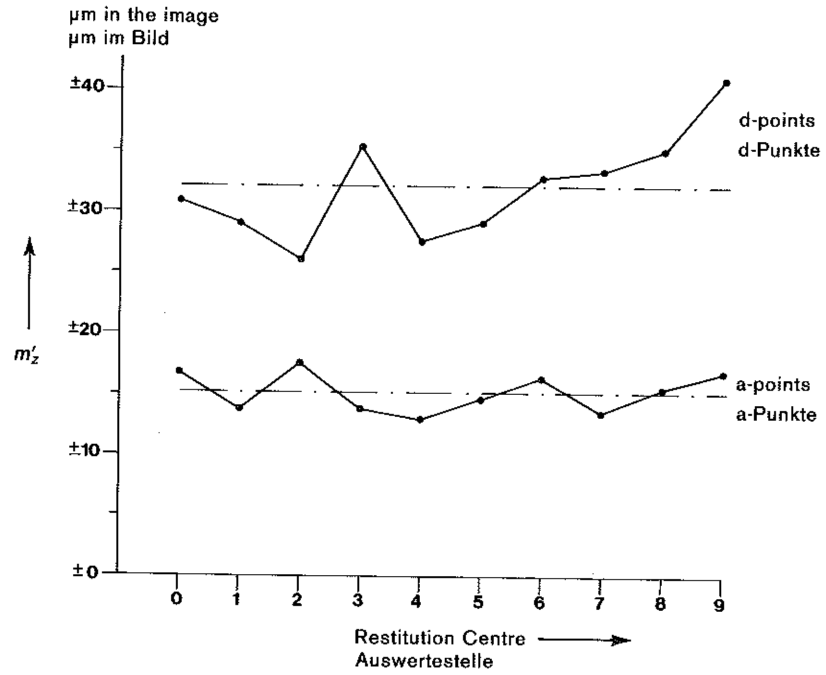
In table 11 we have compiled the standard absolute errors for the single restitu- tions. As done in chapter 5.2.1, we now regroup the results according to the dif- ferent variables (table 15). In particular, we find:

- The standard absolute errors m_k of the four point types in "μm in the image" are for the fundamental test in the proportion of 0.30 : 1.30 : 1.00 : 0.95. The standard error of the a-points m_k = 5.5 μm, that of the b-, c- and d-points 17.2 μm. According to this the ratio of the absolute planimetric error of the signalised points to that of the non-signalised points is about 1.00 : 3.15.
- For the scale 1:3500 the standard absolute error m_k of the a-points in "μm in the image" is 20% larger than for the scale 1:6000. The corresponding errors of the non-signalised points are practically equal.
- For the two operator groups, the standard absolute errors m_k of the a-points as well as those of the non-signalised points are practically equal.
- For the morning and afternoon flights, too, the standard absolute errors m_k of the a-points as well as those of the non-signalised points are practically equal.
- The standard absolute height errors m_z of the four point types are in the pro- portion of 0.50 : 0.75 : 1.00 : 1.00. Striking is the small value for the b- points. The standard absolute height error of the a-points m_z = 15.2 μm (ap- proximately 0.07°/oo of the flight height), that of the b-, c- and d-points m_z = 30.7 μm (approximately 0.15°/oo of the flight height). According to this the ratio of the absolute height error of the signalised points to that of the non-signalised points is about 1.00 : 2.00.
- For the scale 1:3500 the standard absolute errors m_z of the a-points in "μm in the image" are 35% larger, those of the non-signalised points 20% larger than for the scale 1:6000.
- For the two operator groups the standard absolute height errors m_z of the a- points are practically equal. The standard absolute height errors m_z of the non- signalised points are for the 2nd operator group 10% larger than for the 1st operator group.
- For the morning and afternoon flights, too, the standard absolute height errors m_z of the a-points are practically equal. The standard height errors m_z of the non-signalised points are for the afternoon flights 15% smaller than for the morning flights.

Table 10 contains the standard absolute errors for each single Restitution Centre. For this reason we also want to investigate the deviations of these values more closely. However, in doing so we confine ourselves to the a- and d-points since most of the measurements are available for these two groups of points. The ratio between maximum value and minimum value lies normally between V = 1.5 and 3.0



a) planimetric deviations m'_k



b) height deviations m'_z

Figure 10 — Standard absolute deviations m'_k and m'_z in "µm in the image", separated according to Restitution Centres. Mean values from 4 measurements 1, 3, 2, 4 and 5, 7, 6, 8 respectively

(average 2.0). An exception is the restitution 8 of Restitution Centre 5 where V = 4.5. It probably would have been better to reject this model as well (see chapter 3). In practice, however, one will probably mind less if, for the scale 1:6000, the m_k values of the a-points vary between 2 cm and 4 cm as if, for the d-points, these values vary between 6 cm and 16 cm. It attracts attention that, for the scale 1:6000, Restitution Centre 6 has the largest and Restitution Centre 5 the smallest deviations m_{kd}. In order to determine the different accuracies obtained by the Restitution Centres, the standard deviations of the four restitutions by one operator, viz. 1, 3, 2 and 4 and 5, 7, 6 and 8 respectively, were, with the aid of the scale denominator, first converted into "µm in the image" and then averaged (weighted quadratic mean). The results are compiled in table 16. At the same time we computed the standard deviations m_{mk} and m_{mz} respectively of every single restitution of a Restitution Centre. The standard deviations of the mean values m' thus are only half these values. In fig. 10 these mean values of four restitutions each are also represented in graphic form. For the fundamental test we find:

- The standard absolute errors m'_k of the a-points are at all ten Restitution Centres practically equal. Their standard deviation amounts to 0.7 µm in the image, this are approximately 15% of the overall mean. For the d-points the deviation of m'_k is larger. It amounts to 3.6 µm in the image which is about 25% of the overall mean. Here the extreme value of Restitution Centre 6 attracts attention.
- The standard absolute errors m'_z of the a-points are also practically equal at all ten Restitution Centres. Their standard deviation of 1.5 µm in the image, therefore, is very small. It corresponds to 10% of the overall mean. For the d-points as well the deviation of m'_z is relatively small. It amounts to 4.0 µm in the image which is about 15% of the overall mean.
- For the a-points the standard deviations of the mean values obtained by d i f f e r e n t Restitution Centres correspond to the standard deviations of the restitutions performed by the s a m e Restitution Centre. For the d-points, however, they are considerably larger. Here the large value 13.5 µm of m_z obtained by Restitution Centre 5 attracts attention. This deviation is caused by restitution 2 (vide table 16).

For the 2^{nd} operator group the conditions are about the same. On this occasion once more reference is made to the large diviation in the model of restitution 8, Restitution Centre 5. Without this model the corresponding mean value would amount to only 44 µm instead of 52 µm and the standard deviation of the single values would be 20 µm instead of 36 µm.

Comparing the results obtained by the two operators of the same Restitution Centre we find that the mean values m'_k and m'_z are practically equal for the a-points. For the d-points, the large difference between the two values for m'_k and m'_z at Restitution Centre 5 and the correspondingly large values for m'_k at Restitution Centre 6 attract attention (vide fig. 10). Such difference may be caused by systematic errors, but so far the standard absolute deviations of the a-points do not furnish any reason for such an assumption. Without restitution 8, Restitution Centre 5, the standard values of the differences between the mean values obtained by operator 1 and operator 2 amount to approximately 10% of the overall mean for the a-points and to approximately 15% of the overall mean for the d-points.

5.2.3 Relative Accuracy R

In table 12 we have compiled the standard relative errors for the single restitutions. As done in chapter 5.2.1, we regroup the results according to the different variables (table 17). In particular, we find:

- For the fundamental test the standard relative errors m_k of the different point types in "µm in the image" are in the proportion of 0.25 : 1.35 : 1.00 : 1.00 : 0.65. Striking is the small value for the e-points. The standard error of the a-points m_k = 3.7 µm in the image, that of the b-, c-, d- and e-points m_k = 14.1 µm. According to this, the ratio of the relative planimetric errors of the signalised points to that of the non-signalised points is approximately 1.00 : 3.80.
- For the scale 1:3500 the standard relative errors m_k of the a-points in "µm in the image" are 15% larger than for the scale 1:6000. The corresponding errors of the non-signalised points are equally large for both scales.
- For the 2nd operator group the standard relative error m_k of the a-points is 15% larger than for the 1st operator group. The corresponding errors of the non-signalised points are practically equal.
- For the morning and afternoon flights the standard relative errors of the a-points as well as those of the non-signalised points are practically equal.
- The ratio of the standard relative height errors m_z of the different point types are in the proportion of 0.40 : 0.75 : 1.00 : 0.95 : 1.00. The standard relative height error of the a-points m_z = 11.5 µm (approximately 0.05 $^o/oo$ of the flight height), that of the b-, c-, d- and e-points m_z = 28.2 µm (approximately 0.13 $^o/oo$ of the flight height). According to this, the ratio of the relative errors of the signalised points to that of the non-signalised points is about 1.00 : 2.45.
- For the scale 1:3500 the standard relative height errors m_z of the a-points in "µm in the image" are 35% larger, those of the non-signalised points 20% larger than the corresponding errors for the scale 1:6000.
- For the 2nd operator group the standard relative height errors m_z of the a-points are 10% larger, and those of the non-signalised points 15% larger than the corresponding errors for the 1st operator group.
- For the morning and afternoon flights the standard relative height errors m_z of the a-points are equally large. The standard relative height errors m_z of the non-signalised points are 15% smaller for the afternoon flights than for the morning flights.

5.2.4 Systematic Deviations S

In table 13 we have compiled the square averages of the systematic deviations for the single deviations. As done in chapter 5.2.1, we regroup the results according to the different variables (table 18). In particular, we find:

- For the fundamental test the standard systematic errors m_k of the four point types in "µm in the image" are in the proportion of 0.25 : 1.25 :1.00 : 0.85. The standard deviation of the a-points m_k = 2.9 µm, those of the b-, c- and d-points, however, m_k = 11.2 µm. According to this, the ratio of the systematic planimetric deviation of the signalised points to that of the non-signalised points is 1.00 : 3.85.
- For the scale 1:3500 the standard systematic errors m_k of the a-points in "µm in the image" are 35% larger, those of the non-signalised points 20% larger than for the scale 1:6000.
- For the 2nd operator group the standard systematic errors m_k of the a-points are 20% larger, those of the non-signalised points 30% larger than for the 1st operator group.
- For the morning and afternoon flights the standard systematic errors m_k of the a-points are equally large. The standard systematic errors of the non-signalised points are 15% smaller for the afternoon flights than for the morning flights.
- For the fundamental test the standard systematic height errors m_z of the four point types are in the proportion of 0.45 : 0.75 : 1.00 : 1.10. Striking is the small value for the b-points. The standard deviation of the a-points m_z = 8.6 µm and that of the b-, c- and d-points m_z = 20.5 µm. According to this, the ratio of the systematic errors of the signalised points to those of the non-signalised points is about 1.00 : 2.40.
- For the scale 1:3500 the standard systematic height errors m_z of the a-points in "µm in the image" is 40% larger, those of the non-signalised points 30% larger than for the scale 1:6000.
- For the two operator groups the standard systematic height errors m_z of the a-points are practically equal. The standard systematic errors m_z of the non-signalised points are 20% larger for the 2nd operator group than for the 1st operator group.
- For the afternoon flights the standard systematic height errors m_z of the a-points are 15% smaller, those of the non-signalised points 20% smaller than for the morning flights.

In order to determine whether the differences between the absolute errors A and the ralative errors R are statistically significant, i.e. whether systematic errors S are truly available, we test the variances s^2 with Fisher's F-test, namely for an upper and lower significance level of α = 2.5% (see also chapter 6.4). Since we do not have the standard relative errors for each Restitution Centre, we merely compare the standard errors for each restitution (see tables 11 and 12). Instead of the co-ordinate errors m_k we use, of course, the original errors m_x and m_y.

Since $$m_A^2 \neq m_R^2 + m_S^2 \quad (54.41)$$

then $$F \neq m_A^2 : m_R^2 \,. \quad (54.42)$$

This is already demonstrated by the fact that for the heights z of the b-, c- and d-points m_R is in some cases larger than m_A.
Generally

$$f_A \, m_A^2 = f_R \, m_R^2 + m_S^2 \qquad (54.43)$$

(see equations 42.47 - 42.49). Consequently

$$F = \frac{f_A}{f_R} \cdot \frac{m_A^2}{m_R^2} = K \cdot \frac{m_A^2}{m_R^2} \qquad (54.44)$$

For the a-points, f_A is dependent on the number of the stations N_{St}. In the computation of the standard relative errors, the measuring results obtained from strips 1 and 2 were combined for some stations, namely in the case of restitutions 1, 3, 2 and 4 for 28, 41, 5 and 13 stations, in the case of restitutions 5, 7, 6 and 8, however, only for 0, 2, 0 and 1 stations. For this reason we cannot take N_{St} from table 3 but in our case the number of stations N_{St} is for restitutions 1, 3, 2 and 4 : 56, 65, 66 and 68 and for the restitutions 5, 7, 6 and 8 : 47, 52, 37 and 39. The values N_P can be taken from table 12. For the non-signalised points f_A = 1 (vide equation 42.49), f_R in all cases only depends on the number of the measurements i. Since i ≠ const., we replace i by the ratio $N_M : N_P$ (vide chapter 4.2.4). The values N_M are taken from table 12 as well. The results have been compiled in table 19. In particular, we find for the fundamental test:

- The variances s^2 agree in 9 of 44 cases, this are 20%.
- For the a-, c- and d-points the variances do not agree at all, i.e. the differences between the standard absolute errors and the standard relative errors, and thus the systematic errors, are significant. It attracts attention that also for the a-points systematic deviations can be unambiguously proven.
- For the b-points the variances agree in 9 of 12 cases, this are 75%. For these points the number of measurements is probably too low to obtain reliable accuracy values A and R and thus discover significant differences.

For the 2nd operator group the conditions are similar. But here agreements also exist for the heights of the c-points, i.e. the differences between the standard absolute errors and the standard relative errors are in this case not significant.

6. Analysis of the Standard Errors

6.1 Accuracy of the Different Survey Methods (V_A)

In chapter 5 we have compiled the standard errors of the photogrammetric measurements according to different parameters, separated according to error types, viz. measuring error M, absolute error A, relative error R and systematic error S. In order to determine the influence of the different parameters on the accuracy, we compiled in table 20 part of the errors from chapter 5. The standard errors of the terrestrial measurements T refer to the single measurements (vide table 6, columns 4 and 5). These errors are compared with the standard co-ordinate errors m_k and the standard height errors m_z of the photogrammetric measurements, separated according to point types (a-, b-, c-, d-points) and photo scales (restitutions 13 and 24). For the sake of completeness the results of the 2nd operator group (57

and 68) are also indicated. The standard relative errors for the e-points are missing since no corresponding standard errors of the terrestrial measurements are available. Instead we compare the errors of the a-points with the errors of the non-signalised building points (b-, c- and d-points = g-points).

Now we compare the standard errors of the terrestrial measurements with the different errors of the photogrammetric measurements. In table 21 we have compiled the ratios V_A, separately for error types. To the terrestrial measurement we assigned the number 1.00. Thus:

$$T : A : R : S = 1 : V_A(A) : V_A(R) : V_A(S) \qquad (61.01)$$

The smallest value for $V_A(A)$ is 1.62. In the computation of the standard absolute errors of the photogrammetric co-ordinates we used as co-ordinates of comparison the mean obtained from five different terrestrial measurements. The standard errors of these mean values consequently are:

$$M = \frac{m}{\sqrt{5}} \qquad (61.02)$$

(vide table 6, columns 6 and 7). This means that these mean values of the terrestrial co-ordinates are, compared to the standard absolute errors of the photogrammetric measurements, practically free of errors, because in this case $V_A(A)$ = 3.6. However, under unfavourable conditions the systematic errors can be about 10% too large. The V_A-values are, of course, larger for the 1:6000 scale than for the 1:3500 scale. To eliminate the influence of the photo scale, we converted the standard errors to the scale 1:1000 and averaged the V_A-values. This way we can derive the V_A-values for any photo scale because

$$V_A(m_b) = V_A(1000) \cdot m_b \cdot 10^{-3} \qquad (61.03)$$

For this conversion the error data in "μm in the image" of tables 15, 17 and 18 can also be used. In particular, we find from table 21 for the fundamental test:

- The value $V_A(1000)$ for the standard co-ordinate error m_k of the a-points $V_A(1000)$ = 0.40, that for the non-signalised points (g-points), $V_A(1000)$ = 0.80.
- The corresponding values $V_A(1000)$ for the standard height errors m_z, for the a-points as well as for the non-signalised points (g-points), $V_A(1000)$ = 1.15. Very striking is the small value for the b-points and the large value for the c-points.
- For all point types together:

$$V_A(A) : V_A(R) : V_A(S) = 1.00 : 0.80 : 0.60 \qquad (61.04)$$

With $V_A(1000)$ = 0.40 for the standard absolute errors m_k of the a-points all other V_A-values can thus be computed.

6.2 Accuracy of the Different Types of Points (V_P)

In practice it will in most cases be necessary to plumb the roof points because one may either want to present the eaves on a map produced by field survey, or the building walls on a map produced by photogrammetry. Table 6 or table 20 indicate that for the terrestrial measurements, the roof points (c- and d-points) have larger standard errors than the signalised a-points. The difference can be explained partially as plumbing error and partially as additional identification error. The standard errors of the d-points are a little larger than the errors of the c-points; the reason for this may be that the eaves do not exactly form a straight and that the d-points were measured at different places at the end of an eave. We combine the standard errors of the c- and d-points, deduct the standard errors of the a-point and obtain this way a plumbing error (including an identification error) m_l = 1.5 cm. Considering that the standard errors m_k are the mean of two terrestrial measurements of one operator group, the accuracy of one plumbing amounts to approximately 2.0 cm. It attracts attention that with terrestrial measurements the b-points (building corners) have an additional error m_k of about 2.0 cm as compared to the roof points. Even more striking is the large height error of these latter points.

To be able to compare the standard errors of the different point types for the photogrammetric measurements, we again make use of the tables 14, 15, 17 and 18 in chapter 5.2 or of table 20 in chapter 6.1. Since no comparison with the terrestrial measurements is intended, we immediately use the common errors for both scales in "µm in the image". These tables answer already the question which planimetric and height accuracy has been reached for the different point types. For the d- and e-points (eaves and ridges), no measuring accuracy M could be computed. In addition there are no terrestrial comparative measurements for the e-points and, in consequence, no absolute errors (A) and no systematic deviations (S). In particular, we find:

- The a-points actually only serve the purpose to transform the photogrammetric co-ordinates of each station into the system of the terrestrial co-ordinates and thus allow a comparison of the different measurements. The actual standard co-ordinate and height errors of the a-points permit, moreover, to test the aerial photographs with respect to their quality. Each station comprises an area of about 100 m x 100 m in the terrain, i.e. approximately 2 cm x 2 cm at the scale of 1:6000 and about 3 cm x 3 cm at the scale of 1:3500. Within so small an area a number of systematic influences, e.g. caused by refraction or distortion, as well as a part of the instrument errors are constant and therefore are eliminated by means of a transformation. Our standard errors for the a-points are - with m_k = 5.5 µm and m_z = 15 µm ≙ 0.07 °/oo of the flight height - very small as compared with the results obtained in other tests, e.g. [5]. We therefore may assume that the conditions were not particularly unfavourable at the time of our photogrammetric measurements.
- The number of the b-points is very low. For this reason the standard errors of these points are uncertain or inaccurate. We therefore dispensed with a comparison of the results of different restitutions. Already during the reconnaissance we had discovered that it is difficult to find in densely built-up areas corners of houses which are visible from the air and a photographic coverage with a larger overlap would hardly change this. Therefore these points are of no importance in daily practice although they offer the advantage that they need not be plumbed.

We now compare the standard errors of the different point types. In table 22 we

have compiled for restitutions 1234 and 5678 the ratios V_P, separated according to error types. To the standard errors of the c-points, i.e. of the roof corners, we again assign the number 1.00 (see also chapter 5). It attracts notice that - at least for the error values A, R and S - the ratio figures V_P for the co-ordinate errors m_k are nearly equal to these for the height errors m_z. In particular, we find for the fundamental test:

- The standard co-ordinate errors m_k of the different point types are in the proportion of 0.25 : 1.30 : 1.00 :0.95 : 0.65.
  This means that the standard errors m_k of the b-points are approximately 30% larger than those of the c-points.
- The standard errors m_k of the c- and d-points are - as had to be expected - practically equal.
- The standard relative errors m_k of the e-points are about 35% smaller than the corresponding errors of the c- and d-points. Since we can hardly assume that the systematic deviations are larger for the roof ridges than for the roof eaves, also the absolute errors of the e-points would probably be correspondingly smaller than those of the c- or d-points.
- The ratio of the planimetric errors m_k of the a-points to those of the non-signalised points (g-points) is approximately 1.00 : 3.50.
- The standard height errors m_z are of less importance for a building map than the standard planimetric errors. The standard errors m_z of the different point types are in the proportion of 0.45 : 0.75 : 1.00 : 1.00 : 1.00.
- The standard errors m_z of the b-points are - contrary to the planimetric errors - about 25% smaller than those of the c-points. The reason for this should be relatively simple since the b-points are primarily ground points which are more or less comparable with the a-points.
- The standard errors m_z of the c-, d- and e-points are practically equal. The heights of the e-points are - as had to be expected - not more accurate than the heights of the d-points.
- The ratio of the height errors m_z of the a-points to those of the non-signalised errors is approximately 1.00 : 2.25.

Considering that the standard co-ordinate errors m_k and height errors m_z of the a-points are in the proportion of 1.00 : 2.95, the values V_P for the four error values, namely m_k for the a- and g-points and m_z for the a- and g-points, are in the proportion of 1 : 3.5 : 3.0 : 6.5 or simply 1: 3 : 3 : 6. We obtain the equal values when we combine the ratios of the values V_A from chapter 6.1, namely 1 : 2 : 3 : 3, with the corresponding ratios of the standard errors of the terrestrial measurements from chapter 5.1, namely 1 : 1.5 : 1 : 2. With V_A(1000) = 0.40 all other V_A-values can be computed and from that, with m_k = 1.3 cm of the a-points, all other standard errors.

In this connection it may be of interest to find out what influence the transformation by means of the a-points has on the computed accuracy values of the b-, c-, d- and the e-points. For the computation of the standard errors of the transformation parameters we assume that the terrestrial co-ordinates are free of errors,

i.e. that they have the weight infinite. We transform from the terrestrial into the photogrammetric system. The inverse transformation which is actually needed furnishes equally accurate parameters but with inverse sign (vide, e.g., [6]).
The transformation formulae be:

$$x_t \cos\alpha - y_t \sin\alpha + x_o = x_p$$
$$x_t \sin\alpha + y_t \cos\alpha + y_o = y_p \qquad (62.01)$$

With an approximated rotation (α_o) we obtain after the linearisation of the equations

$$-(x_t \sin\alpha_o + y_t \cos\alpha_o)\,\Delta\alpha + x_o = x_p - (x_t \cos\alpha_o - y_t \sin\alpha_o)$$
$$(x_t \cos\alpha_o - y_t \sin\alpha_o)\,\Delta\alpha + y_o = y_p - (x_t \sin\alpha_o + y_t \cos\alpha_o) \qquad (62.02$$

With

$$x_t \sin\alpha_o + y_t \cos\alpha_o = \bar{y}_t$$
$$x_t \cos\alpha_o - y_t \sin\alpha_o = \bar{x}_t \qquad (62.03)$$

results, from equations (62.02),

$$-\bar{y}_t\,\Delta\alpha + x_o = x_p - \bar{x}_t$$
$$\bar{x}_t\,\Delta\alpha + y_o = y_o - \bar{y}_t \qquad (62.04)$$

The normal equation matrix A then reads

$$A = \begin{Vmatrix} \Sigma\,(\bar{x}_t^2 + \bar{y}_t^2) & -\Sigma\bar{y}_t & +\Sigma\bar{x}_t \\ -\Sigma\bar{y}_t & n & 0 \\ +\Sigma\bar{x}_t & 0 & n \end{Vmatrix} \qquad (62.05)$$

Here n is the number of the a-points for the transformation. Using the terrestrial co-ordinates x_t and y_t which are referred to the centre of gravity, then

$$\Sigma\bar{x}_t = \Sigma\bar{y}_t = 0 \qquad (62.06)$$

This way the inverse of the normal equation matrix becomes:

$$A^{-1} = \begin{Vmatrix} \frac{1}{\Sigma\,(\bar{x}_t^2 + \bar{y}_t^2)} & 0 & 0 \\ 0 & \frac{1}{n} & 0 \\ 0 & 0 & \frac{1}{n} \end{Vmatrix} \qquad (62.07$$

The influence of the transformation on the non-signalised points is

$$m_x^2\ (\text{trans}) = \bar{y}_t^2\, m_{\Delta\alpha}^2 + m_{xo}^2$$
$$m_y^2\ (\text{trans}) = \bar{x}_t^2\, m_{\Delta\alpha}^2 + m_{yo}^2 \qquad (62.08)$$

Since an entire station is located within a square of approximately 100 m x 100 m we assume that the distances of the a-points from their respective centre of gravity be approximately:

$$s = \sqrt{\bar{x}_t^2 + \bar{y}_t^2} = 50 \text{ m}$$

Also the non-signalised points are located not farther than about 50 m from the centre of gravity of the a-points, i.e.

$$\bar{x}_t(\text{max}) = \bar{y}_t(\text{max}) = 50 \text{ m}$$

Since in our case for the most part n = 4, we obtain as maximum values from equation (62.08):

$$m_x^2\ (\text{trans}) = m_y^2\ (\text{trans}) = (50\ \frac{1}{4\text{x}50^2} + \frac{1}{4})\ m_{ka}^2 = \frac{1}{2}\ m_{ka}^2$$

With the value m_k = 5.5 µm in the image (see table 15) the maximum values for m_k (trans) consequently are

for the scale 1:6000: m_k (trans) = 2.3 cm

for the scale 1:3500: m_k (trans) = 1.4 cm

Theoretically the standard errors for the b-, c-, d- and e-points should be corrected correspondingly. But the influence amounts to only 1 to 2 mm. This difference has no significance for the practice.

To the heights applies, in principle, the same. However, the heights have only been displaced in parallel direction. It is true that the standard height error of the signalised points m_{za} amounts to 15 µm. However, also the standard errors of the non-signalised points are proportionally larger than the planimetric errors, so that also here a correction would be without significance.

6.3 Accuracy of the Different Photo Scales (V_M)

To be able to determine the standard errors for the different photo scales we again make use of tables 14, 15, 17 and 18 of chapter 5.2 or of table 20 in chapter 6.1. These tables answer already the question as to which planimetric and height accuracy can be reached for the two photo scales. We dispense with indicating the single values once more but combine in table 23 for the restitutions 13 and 24 as well as 57 and 68 the ratios V_M, separately for the error types. To the standard errors for the scale 1:6000 we assign the value 1.00. Thus we find, e.g., for the measuring accuracy M of the a-points from table 14 the ratio 1 : V_M(M) = restitution 13 : restitution 24 = 3.3 µm : 2.8 µm = 1 : 0.85.

For the co-ordinate errors m_k as well as for the height errors m_z the ratio figures V_M for the error values A, R and S are again almost equal. In particular, we find for the fundamental test:

- The standard measuring errors m_k of the a-points in "µm in the image" are about 15% smaller for the photo scale 1:3500 than for the photo scale 1:6000. With an error of only 3 µm the difference is insignificant. The corresponding errors m_k

of the non-signalised points (g-points) are equally large for both scales.

- For the other error types (A, R and S) the standard co-ordinate errors m_k of the a-points are for the 1:3500 scale about 20% larger, those of the non-signalised points about 10% larger than for the 1:6000 scale.
- For the scale 1:3500 the standard measuring errors m_z of the a-points in "µm in the image" as well as those of the non-signalised points are about 10% smaller than for the scale 1:6000.
- For the other error types (A, R and S) the standard height errors m_z of the a-points are for the scale 1:3500 approximately 35% larger, those of the non-signalised points, however, about 20% larger than for the scale 1:6000.

Apart from the measuring errors we thus obtain for the other error types at a small scale (1:6000) smaller errors than at a large scale (1:3500). This tendency is stronger for the height errors m_z than for the co-ordinate errors m_k. The proportions are, of course, inverse when we calculate with errors in "cm in the terrain".

6.4 Accuracy Obtained by Different Observers (V_B)

As mentioned before, every Restitution Centre should - if at all possible - make two operators available. The 1st operators carried out the fundamental restitutions (1 to 4); the 2nd operators repeated part of the measurements (restitutions 5 to 8). In order to find out whether the accuracy reached by the two operator groups varied, we go back to restitutions 1234 and 1467 of tables 14, 15, 17 and 18. In table 24 we have compiled the ratios V_B of the respective standard errors. To the standard errors of the 1st operator group we assign the value 1.00. This way we find, e.g. for the measuring errors M of the a-points from table 14 the ratio 1 : V_B = operator group 1 : operator group 2 = 3.0 µm : 3.5 µm = 1 : 1.17.

In particular, we find:

- For the 2nd operator group the standard measuring errors m_k of the a-points in "µm in the image" are about 15% larger, those of the non-signalised points (g-points) about 20% larger than for the 1st operator group.
- For the other types (A, R and S) the standard co-ordinate errors m_k of the a-points and those of the non-signalised points are for the 2nd operator group 10% larger than for the 1st operator group. Worth noticing are perhaps the larger systematic errors and the somewhat smaller relative errors of the 2nd operator group for the g-points. The absolute errors are nevertheless practically equal.
- For the measuring accuracy M the standard height errors m_z of the a-points in "µm in the image" are for both operator groups equal but as far as the standard height errors m_z of the non-signalised points are concerned, they are for the second group about 25% larger than for the first group.
- For the other error types (A, R and S) the standard height errors m_z of the a-points of the 2nd operator group are only about 5% larger, those of the non-signalised points about 15% larger than for the 1st operator group.

Although the number of operators and the number of measurements are different for both operator groups, it cannot be seen why the standard errors of both groups should not be equal. Even if we separate the measurements according to photo scales we find that for the 2nd operator group the standard errors are in both cases approximately 15% larger than for the 1st operator group. While drawing this comparison it should be noted that not all of the Restitution Centres were in the position to make two operators available, but that for the 2nd operator group only the measurements of seven restitutions were available and that these only comprised part of the measurements taken by the first operators. Other "parameters" such as restitution instrument, film diapositives, outward circumstances, can, however, be assumed to be equal. In order to avoid any inhomogenity we select for a comparison only those points which were measured by both operators. Initial values are the differences Δx, Δy and Δz between the terrestrially determined co-ordinates and the photogrammetrically determined co-ordinates of identical points of measurements 1 and 5, 2 and 6, 3 and 7 and 4 and 8. From these differences we compute for all points each of a point group the standard value

$$\Delta\bar{q}_i = \frac{[\Delta q_i]}{N_P} \quad (q \equiv x, y, z; \quad i \equiv 1, 2) \qquad (64.01)$$

and the variances

$$s_i^2 = \frac{[(\Delta q_i - \Delta\bar{q}_i)^2]}{N_P - 1} \qquad (64.02)$$

From this we then obtain

$$t = \frac{\Delta\bar{q}_1 - \Delta\bar{q}_2}{\sqrt{\dfrac{s_1^2 + s_2^2}{N_P}}} \qquad (64.03)$$

and

$$F = \frac{s_1^2}{s_2^2} \quad \text{and} \quad \frac{s_2^2}{s_1^2} \quad \text{resp.} \qquad (64.04)$$

In order to find out whether the differences are statistically significant or not, i.e. whether the results are really different or agree, we tested the standard values $\Delta\bar{q}$ with Student's t-test and the variances s^2 with Fisher's F-test, namely for an upper and lower significance level of α = 2.5%. The single results for the mean values of the $\Delta\bar{q}$ (t-test) are compiled in table 25 and for the comparison of the variances s^2 (F-test) the values s = m are combined in table 26 (see also table 10). Table 27 contains the compilation of the results, separately for point types and photo scales, whereas in table 28 the results are separated according to Restitution Centres. For the a-points the t-test is missing because, on account of the transformation with these points, $\Delta\bar{q}_1 = \Delta\bar{q}_2 = 0$ at all times. Due to the low number of measurements in both cases the b-points were omitted as well. From tables 25 and 27 we find for the t-test:

- The mean values $\Delta\bar{q}$ agree statistically in about 75% of the cases, i.e. for the c-points in 80% and for the d-points in 65% of the cases. This does not preclude systematic errors though because in many cases the value $\Delta\bar{q}$ deviates considerably from the expectation "0". Furthermore the differences between two corresponding $\Delta\bar{q}$-values are in general smaller than the $\Delta\bar{q}$-values themselves. However, the systematic parts differ from one Restitution Centre to the other.

- The mean values $\Delta\bar{x}$ and $\Delta\bar{y}$ agree in 80% of the cases, the values $\Delta\bar{z}$ in 65% of the cases.

From tables 26 and 27 we find for the F-test:

- The variances s^2 agree in about 65% of the cases, i.e. for the a-points in about 75%, for the c-points in 70% and for the d-points in 50% of the cases.
- The variances s^2 for x and y agree in 70% and for z in 65% of the cases.

Combining the results of both tests (see table 28) we find for the Restitution Centres 0, 4, 9 an agreement of 85%, for the Restitution Centres 6, 7 and 8 an agreement of 65% but for Restitution Centre 5 only an agreement of 45%. Considering that for the c- and d-points the results of both tests are available we also mention that these results agree for the c-points only in 60%, for the d-points in 50%, for the x-, y-values in 60% and for the z-values in 50% of the cases.

6.5 Accuracy at Different Sun Positions (V_S)

Within the scope of this test the influence of an azimuthal change of the illumination direction is to be determined. For this purpose for each photo scale two flights were performed at different times of the day, namely one in the morning and one in the afternoon.

We again go back to tables 14, 15, 17 and 18 of chapter 5. In table 29 we compiled for restitutions 12 and 34 and 56 and 78 respectively the ratios V_S of the respective standard errors. To the standard errors for the flight in the morning we assign the value 1.00. We thus find, e.g. for the measurring accuracy M of the a-points from table 14 the ratio 1 : V_S = restitution 12 : restitution 34 = 2.9 μm : 3.1 μm = 1.0 : 1.07.

In particular, we find for the fundamental test:

- For both flights the standard measuring errors m_k of the a-points in "μm in the image" as well as those of the non-signalised points (g-points) are equal.
- For the other error types (A, R and S) the standard errors m_k of the a-points are also equally large. For the afternoon flights, however, the standard errors of the non-signalised points (g-points) are approximately 10% smaller than for the morning flights. Larger differences are found in particular for the systematic deviations.
- For both flights the standard height errors m_z of the a-points in "μm in the image" are practically equal. However, the standard height errors m_z of the non-signalised points (g-points) are for the afternoon flights about 10% smaller than for the morning flights.
- For the other error types (A, R and S) the standard height errors m_z of the a-points are for the afternoon flights approximately 10% smaller, those of the non-signalised points (g-points), however, about 15% smaller than for the morning flights.

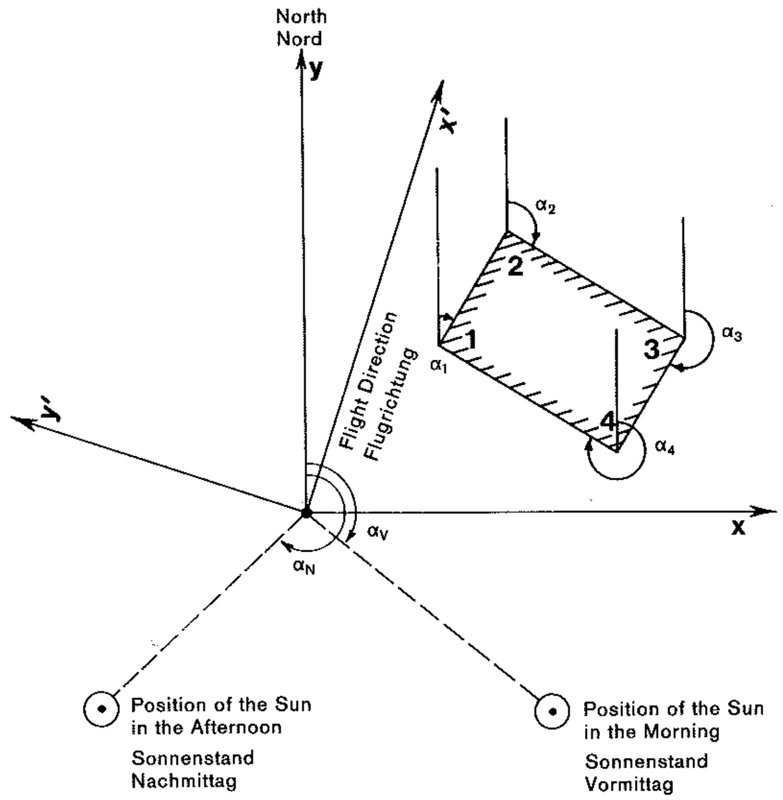
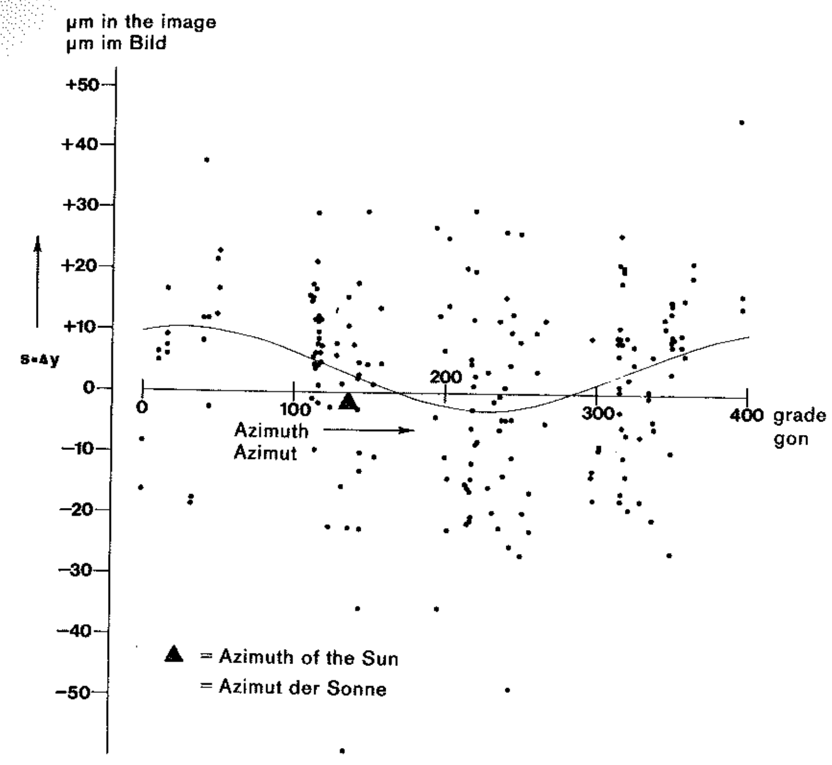
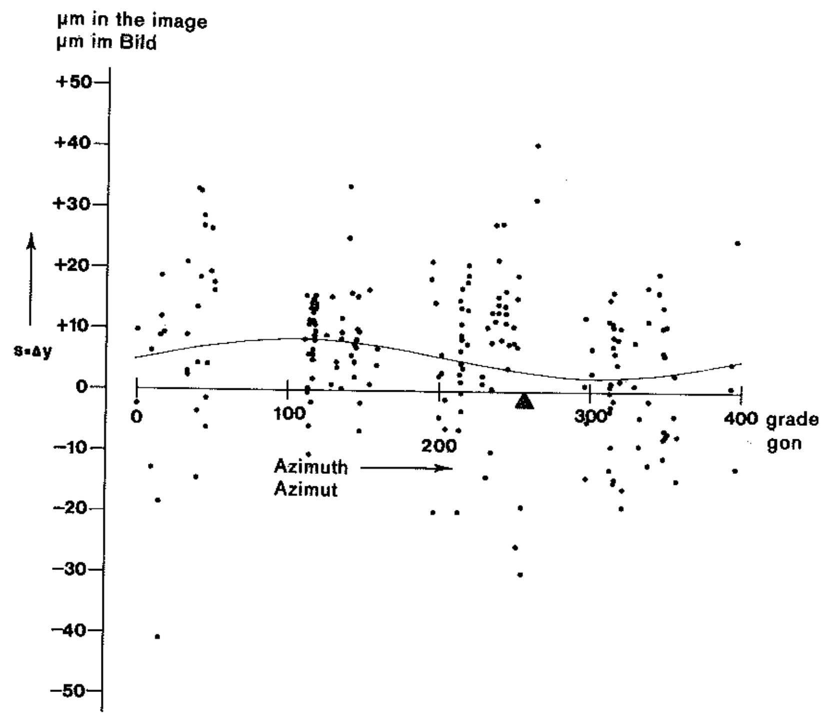


Figure 11 — The definition of the azimuth of a roof eave

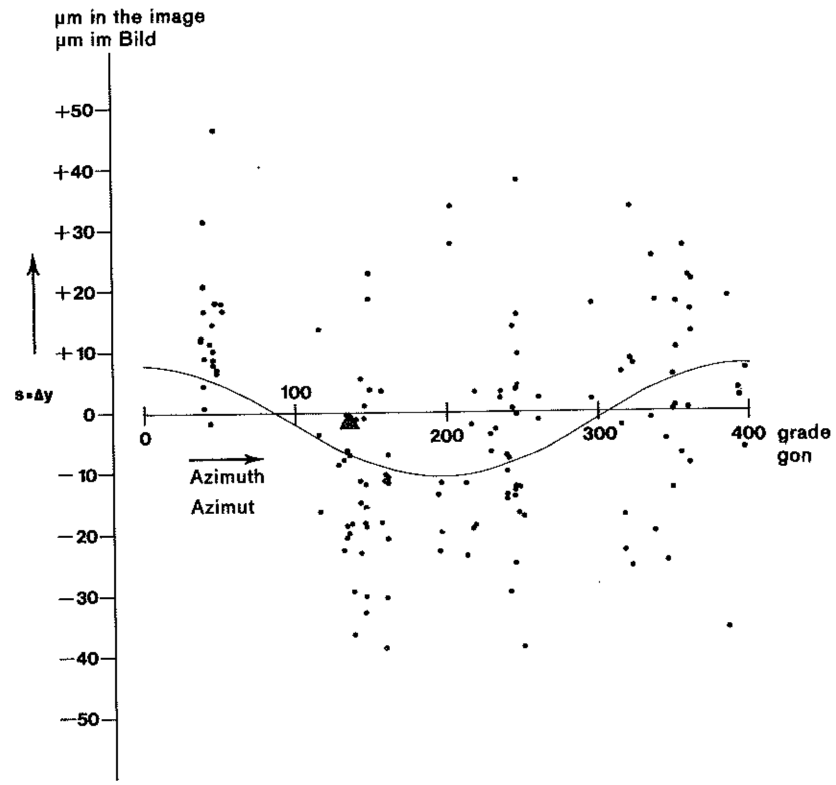


a) s_1 — scale 1 : 6000, in the morning

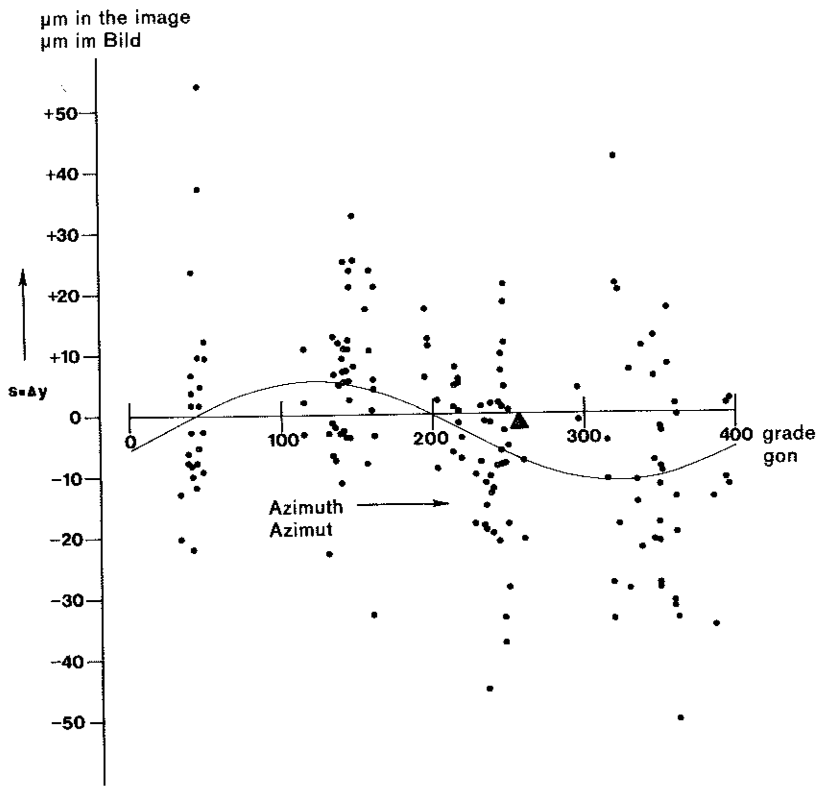


b) s_2 — scale 1 : 6000, in the afternoon

Figure 12 — Horizontal deviations $s = \Delta y$ of the photogrammetrically measured roof points (d-points) from the terrestrially determined d-line as function of the azimuth α of the corresponding roof eave, referred to the north direction



c) s_3 — scale 1 : 3500, in the morning



d) s_4 — scale 1 : 3500, in the afternoon

Figure 12 *continued*

The standard errors for the afternoon flights are a little less than 10% smaller than for the morning flights though, but since the roof eaves lie under different azimuths it cannot be seen why the standard errors are to depend on the azimuth of the sun. This does not preclude, however, that there is a systematic displacement for each single eave, depending on the position of the sun.

After all we found already considerable standard systematic deviations. They amount for the signalised points (a-points) to m_k = 3 µm and m_z = 8.5 µm in the photograph, for the non-signalised points (g-points) to m_k = 11 µm and m_z = 20.5 µm (see chapter 5.2.4 table 18). Furthermore we find (see chapter 6.1) that, for the co-ordinate errors m_k as well as for the height errors m_z, the systematic deviations amount to about 80% of the relative errors. The investigations on the results obtained by the two operators of one Restitution Centre in chapter 6.4 also point to systematic deviations. In this connection we have mentioned already that the area of a station is relatively small in the photograph and that for this reason refraction, lens distortion, film deformations, etc. hardly influence the accuracy of our results. In the "ideal case" the absolute errors and the relative errors ought to correspond to the measuring errors. The difference between the measuring errors M and the relative errors R can be explained by additional instrumental and identification errors. For the signalised points (a-points) they amount to m_k = 1.5 µm and m_z = 7.5 µm in the image, for the non-signalised points (g-points) to m_k = 14 µm and m_z = 27 µm. The differences between the relative errors R and the absolute errors A are largely caused by the systematic deviations S. One should think that the "ideal case" could be reached for the a-points since in their case the interpretation and identification errors are largely eliminated by the signalisation, but even the a-points are evidently not free of systematic influences as here the differences between both error types amount to m_k = 1.5 µm and m_z = 11 µm in the photograph. The corresponding values for the non-signalised points are 10 µm and 12 µm respectively.

In order to really determine the influence of the azimuthal change of the illumination direction we once again go back to the single measurements. For these investigations we use the d-lines and the d-points respectively. It is understood that only those eaves are dealt with which were measured in both the morning and the afternoon flights. First we calculate for each eave the azimuth. Its definition is shown in fig. 11. The eaves are numbered quasi clockwise. If we look from one roof corner to the next one, the building is always located at the right-hand side. To each d-point we now assign the horizontal deviation s of the photogrammetrically measured roof point from the terrestrially determined d-line (the distances s correspond to the values Δy of chapter 4.2.2, item 2.3). A positive distance s means that the photogrammetrically measured point is located outside the building. For the single measurements of each Restitution Centre we have now represented in graphic form the s-values as function of the azimuth. Fig. 12 shows some examples which clearly indicate that, on the one side, there is a preferred building direction in the test area, since the azimuths of the roof eaves are not evenly distributed, but that, on the other side, the dependency of the s-values on the azimuth varies for all measurements. In order to analyse this dependency we calculated by means of the least squares method for each measurement a simple

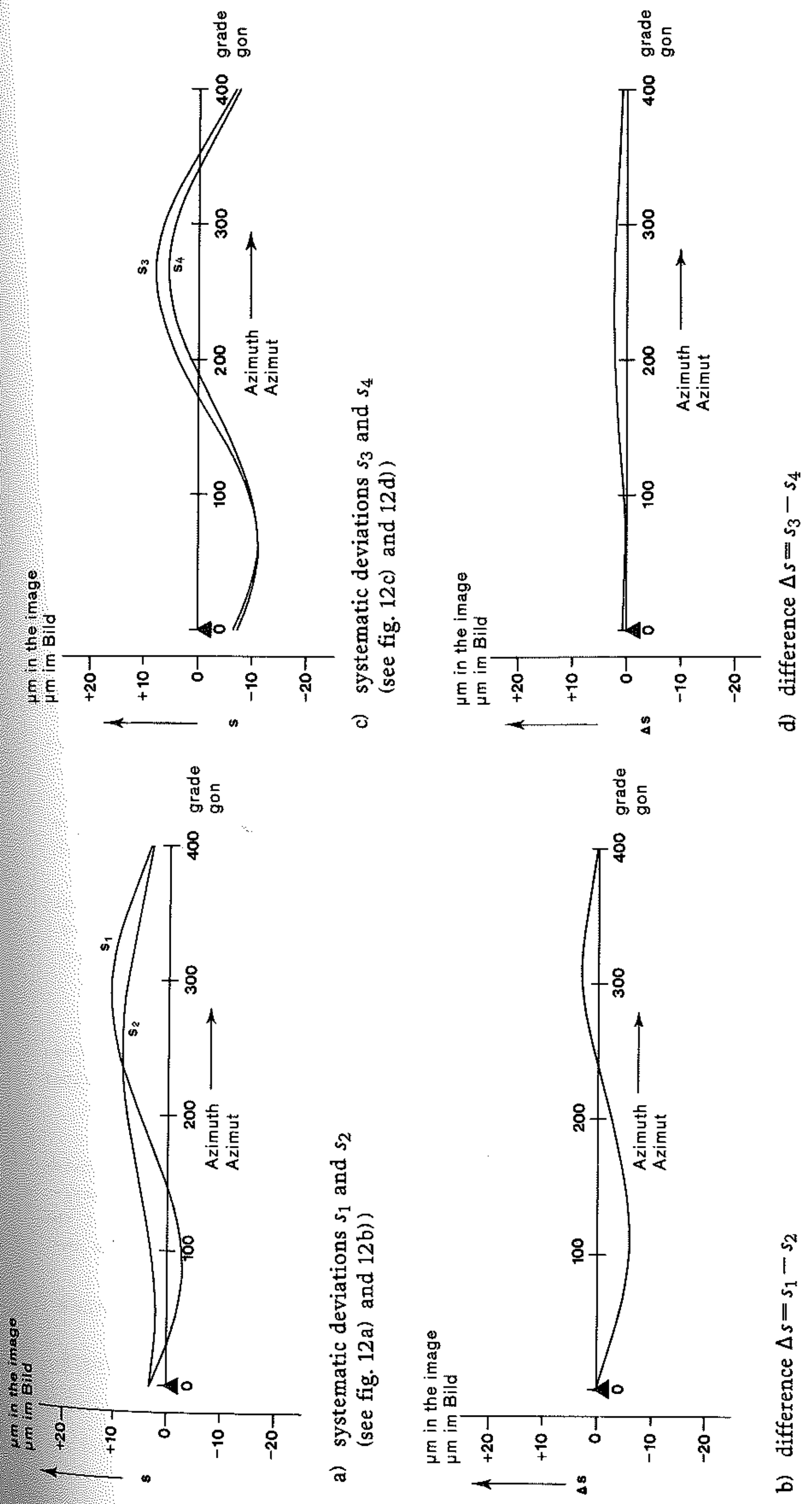


Figure 13 — The systematic part of the horizontal deviation s of the d-points as function of the azimuth of the roof eaves, but referred to the azimuth of the sun, as well as the differences Δs resulting from the flights in the morning and in the afternoon.

sine curve according to equation

$$s = a_o + a_1 \cdot \sin(\alpha + \alpha_o) \qquad (65.01)$$

a_o is a constant personal measuring error of the operator.
a_1 is the amplitude of the influence which depends on the azimuth of the roof eave and α_o is a phase shift connected with the azimuth of the sun at the time of the aerial photography. In table 30 we have compiled the results of the individual adjustments. This systematic part s of the horizontal deviation s of the d-points is represented in fig. 12 as function of the azimuth of the roof eaves - referred to the north direction. Fig. 13 shows the systematic parts s but this time referred to the azimuth of the sun.

We also compute the quadratic average s_o of s according to equation

$$s_o^2 = \int_o^{2\pi} s^2 d\alpha : \int_o^{2\pi} d\alpha = a_o^2 + \frac{a_1^2}{2} \qquad (65.02)$$

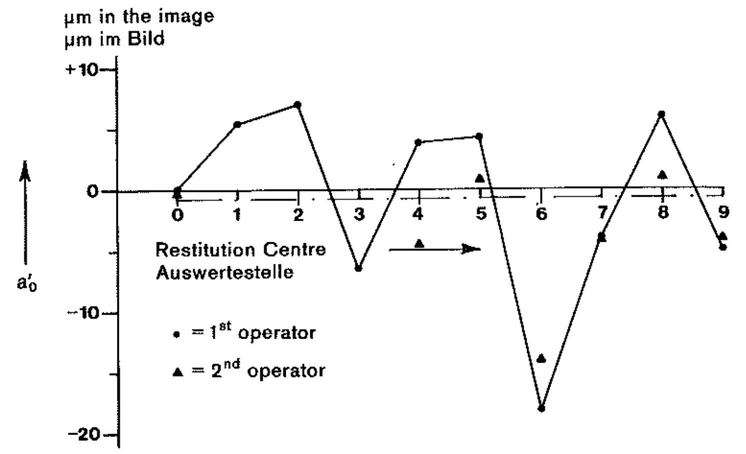
(see table 30).

All the values a_1 are positive. This must not be like this because:

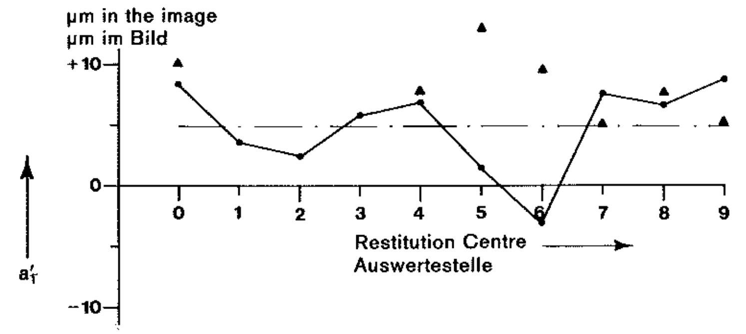
$$a_1 \sin(\alpha + \alpha_o) = - a_1 \sin(\alpha + \alpha_o \pm 200^g) \qquad (65.03)$$

The function thus is preserved when α_o is enlarged or reduced by 200^g and when, at the same time, the sign of a_1 is changed. As far as the values α_o for the flights in the morning or in the afternoon seemed to agree, we formed a mean value each and changed all doubtful values α_o in such a manner that they do not deviate m o r e than 100^g from the provisional mean. This constitutes a certain arbitrariness which cannot be eliminated so easily. The values of restitution 2, Restitution Centres 2 and 6, and of restitution 7, Restitution Centres 4 and 7, are particularly contentious. Table 31 contains the average values $\bar{a}_o$, $\bar{a}_1$, $\bar{s}_o$ and $\bar{\alpha}_o$ for each restitution. As far as the values α_o were changed by 200^g and by this the sign of a_1, this has been indicated in the next to the last column of table 30. With a shift of 400^g the sign of a_1 is, of course, not changed. In order to eliminate the influence of the photo scale we convert the values $\bar{a}_o$, $\bar{a}_1$ and $\bar{s}_o$ in "µm in the image". From the deviations as compared with the respective average value we additionally calculate the standard deviations m_{ao}, m_{a1}, m_{so} and $m_{\alpha o}$ of the values a_o, a_1, s_o and α_o. In particular, we find for the fundamental test:

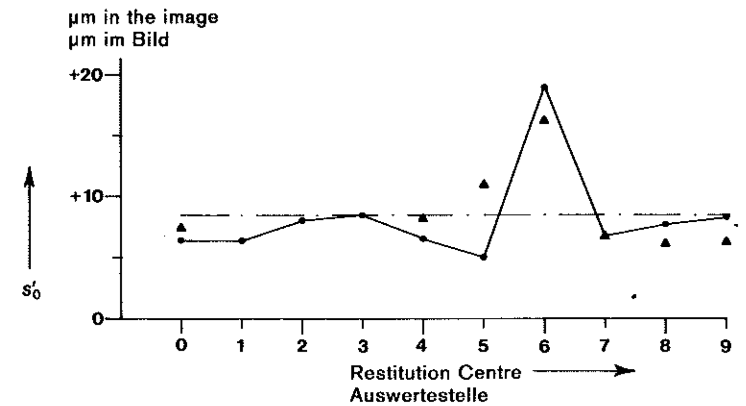
- The average values $\bar{a}_o$ are very small; calculated from the absolute values, they amount to about 1.5 µm in the photograph. The deviation m_{ao} of the single values a_o is relatively large, amounting to approximately 8 µm. This represents the personal error of an operator.
- The average values $\bar{a}_1$ are larger than the values $\bar{a}_o$. They amount to approximately $\bar{a}_1$ = 5 µm in the photograph. This additional error corresponds to the "maximum" influence caused by the azimuth of the roof eaves. The deviation m_{a1} of the single values a_1 is also relatively large, amounting to about 5.5 µm in the image.
- The average values $\bar{s}_o$ are about 8.5 µm in the image. The deviation m_{so} of the single values s_o amounts to approximately 4.5 µm.



a) parts a'_0



b) parts a'_1



c) mean values s'_0

Figure 14 — Systematic planimetric deviations of the d-points in "µm in the image". Mean of 4 single restitutions of one Restitution Centre

- The average values for α_o amount to $\alpha_{o,V} = 72^g$ for the morning flights and to $\alpha_{o,N} = 354^g$ for the afternoon flights. The deviation $m_{\alpha o}$ of the single values is, of course, very large, amounting to approximately $m_{\alpha o} = 45^g$ in both cases.

As computing test serves, by the way, the equation:

$$\bar{s}_o^2 + \frac{n-1}{n} m_{so}^2 = \bar{a}_o^2 + \frac{\bar{a}_1^2}{2} + \frac{n-1}{n} (m_{ao}^2 + \frac{m_{a1}^2}{2}) \qquad (65.04)$$

The right and left side of this equation (65.04) correspond to $m_s^2 = [s_o^2] : n$. From table 30 we find for the 1st operator group $m_s = 9.5$ µm, for the 2nd operator group, however, 10.5 µm. These values are a little smaller than the values m_s from table 18. A part of about 5 µm and 8.5 µm respectively is missing.

Table 30 contains for each restitution the values a_o and a_1 of the systematic deviations according to equation (65.01), but separately for Restitution Centres. These values vary considerably (see table 31). It attracts notice that the largest deviations for the scale 1:6000 as well as for the scale 1:3500 occur at Restitution Centre 6. In order to determine the differences for the single Restitution Centres, the values of the four restitutions, 1, 3, 2 and 4 as well as 5, 7, 6 and 8 of one operator were first converted into "µm in the image" by means of the scale denominator and subsequently averaged. We dispensed with the computations for α_o. The results are compiled in table 32. At the same time we calculated the deviations m_{ao}, m_{a1} and m_{so} of each single restitution of a Restitution Centre. The deviations of the mean values a_o', a_1' and s_o' obtained from the four measurements are only half the amount.

In fig. 14 these mean values are represented in graphic form. In particular, we find for the fundamental test:

- The average of the values a_o', calculated from the absolute values, amounts to approximately 6.0 µm in the image. The deviation m_{ao} of the single values a_o is relatively small, amounting to about 3.0 µm. This is again the personal error of an operator. The deviation of the mean a_o' obtained from the four values of the s a m e Restitution Centre thus amounts to 1.5 µm. Compared to this the deviation obtained from the ten mean values of d i f f e r e n t Restitution Centres is considerably larger, it amounts to about 8 µm. This is a sign for systematic errors on the part of the single operators.
- The average of the values a_1', calculated from the absolute values, amounts to approximately 5.5 µm in the photograph. The deviation m_{a1} of the single values a_1 amounts to 5 µm. The deviation of the mean a'_1 obtained from the four values of the s a m e Restitution Centre thus is 2.5 µm. The deviation of the ten mean values of d i f f e r e n t Restitution Centres amounts to 3.5 µm though. Here the difference is considerably smaller. As is known, the sign of the a_1-values is sometimes uncertain on account of the assignment of α_o.
- For the values s'_o the proportion of maximum value to the minimum value is $V = 4$. The large value reached by the Restitution Centre 6 is very striking (see also chapter 5.2.2). On the average $s_o' = 8.5$ µm in the image. The deviation m_{so} of the single values s_o amounts to 3 µm. The deviation of the mean s_o' obtained from the four values of the s a m e Restitution Centre thus is 1.5 µm, that obtained

from the ten mean values of d i f f e r e n t Restitution Centres amounts, however, to 4 µm.

For the 2nd operator group the conditions are similar. Here, too, attention is drawn once again to the large errors for the models of Restitution Centre 6. This applies to a_o as well as to s_o while for a_1 the differences point at a certain uncertainty of these values. The similarity of the standard systematic deviations a_1 in fig. 14 with the standard absolute deviations in fig. 10 is unmistakable.

The deviations of the mean values a_o', a_1' and s_o' of d i f f e r e n t Restitution Centres are a little smaller than the corresponding deviations of the single values a_o, a_1 and s_o in table 31. The differences are caused by the deviations of the single values of the <u>same</u> operator (vide table 32).

In order to determine in the same way how the values a_o, a_1 and s_o obtained from the morning and afternoon flights agree for the single Restitution Centres, we additionally compute the differences da_o, da_1 and ds_o for these two flights, i.e. the differences of the values a_o, a_1 and s_o of the restitutions 1 and 3, 2 and 4, etc. from table 30. From this we also derive the deviations m_{ao}, m_{a1} and m_{so} of the values a_o, a_1 and s_o. The results are combined in table 33, again converted into "µm in the image". In particular, we find for the fundamental test:

- The average values $\bar{d}a_o$ amount to approximately 2 µm in the photograph. From the differences da_o we find that the standard deviation of a value a_o is $m_{ao} = 3$ µm.
- The average values $\bar{d}a_1$, calculated from the absolute values, amount to about 2 µm in the photograph. From the differences da_1 we find that the standard deviation of a value a_1 is $m_{a1} = 5$ µm.
- The average values $\bar{d}s_o$, calculated from the absolute values, also amount to about 2 µm in the image. From the differences ds_o we find that the standard deviation of a value s_o is $m_{so} = 3$ µm.

These deviations correspond to the values m_{ao}, m_{a1} and m_{so} (<u>same</u> Restitution Centre and <u>same</u> operator) in table 32. They are, however, considerably smaller than the deviations of the values of <u>different</u> Restitution Centres (vide tables 31 and 32). This means that the personal errors of one operator agree well with the different restitutions. But there are operators with a very small personal error and others with a relatively large one.

We also notice that at some Restitution Centres the "personal" errors of the two operators are nearly equal, i.e. both the operators measure almost equally "erroneously". The comparison of the values $\Delta\bar{q}$ in chapter 6.4 indicated this already (see also fig. 14). This may be caused by the photo material, the restitution instrument or by other factors which we considered to be constant for a Restitution Centre. It could also be that the two operators of a Restitution Centre have received a similar training and that this is the reason for their making similar systematic errors.

For this reason we calculate from the differences of the mean values a_o', a_1' and s_o' obtained by the two operators of the same Restitution Centre the standard deviations of these values. The results have been added in table 32 below. Although these deviations are larger than the corresponding values for the same operators of a Restitution Centre, they are nevertheless considerably smaller than the corresponding deviations of the values a_o', a_1' and s_o' reached at different Restitution Centres. This means that the suspicion as to "constant" errors on the part of the two operators of a Restitution Centre is well-founded.

In order to prove this fact with additional figures we also calculate the differences da_o, da_1 and ds_o for the two operators of the same Restitution Centre, i.e. the differences of the single values a_o, a_1 and s_o of the restitutions 1 and 5, 3 and 7, etc. from table 30. From this we again derive the deviations m_{ao}, m_{a1} and m_{so} of the values a_o, a_1 and s_o. The results are contained in table 33, again converted into "µm in the image". In particular, we find:

- The average values $\bar{da}_o$ amount to about 3 µm in the image. From the differences da_o we find that the standard deviation of the single values a_o is m_{ao} = 4.0 µm. This deviation is again a little larger than the corresponding value for the same operator of a Restitution Centre. But it is also considerably smaller than the corresponding deviation of the values a_o obtained at different Restitution Centres.
- The average values $\bar{da}_1$, calculated from the absolute values, amount to approximately 4.0 µm in the image. From the differences da_1 we find that the standard deviation of the values a_1 is m_{a1} = 6.5 µm. This deviation is larger than the corresponding deviation of the values a_1 reached at different Restitution Centres.
- The average values $\bar{ds}_o$, calculated from the absolute values, amount to about 1.5 µm in the image. From the differences ds_o we find that the deviation of the values s_o is m_{so} = 3.5 µm. Here applies the same as to a_o.

The results of a_o and s_o confirm in this case, too, the suspicion as to "constant" errors on the part of the two operators of a Restitution Centre.

From equation (65.01) results that the influence of the azimuth disappears when

$$\alpha = - \alpha_o \pm 200^g$$

With the values for α_o from table 31 results:

- for the morning flights: $\alpha_V = 128^g$ and 131^g respectively
- for the afternoon flights: $\alpha_N = 246^g$ and 283^g respectively.

From the geographic data, the time and under consideration of the convergence of meridian results, however:

- for the morning flights: $\alpha_V = 133^g$
- for the afternoon flights: $\alpha_N = 252^g$.

Considering that the amplitudes a_1 amount to only 6.5 µm, that the values α_o in table 30 were only determined with a standard error of approximately $\pm 45^g$ and that in some cases the phase shift of 200^g was probably used erroneously or partially forgotten, then we may look upon the agreement of the values α_V and α_N as being truly sufficient.

7. Result

7.1 Result of the Analysis

In table 34 we have compiled some of the errors discussed in chapters 4 and 5 to allow a better review. We first distinguish following variables:

- Survey procedure. For the photogrammetric measurements we distinguish the measuring accuracy M, the absolute accuracy A, the relative accuracy R and the systematic deviations S.
- Co-ordinate errors m_k and height errors m_z, i.e. for the terrestrial measurements in "cm in the terrain", for the photogrammetric measurements in "µm in the image".
- Type of point.

We also indicate the number of the measurements N_M and the number of points N_P. The next to the last column contains the reference to the tables from which the figures have been taken. The last column contains the ratio of the standard errors of the non-signalised points (g-points) as compared to those of the signalised points (a-points). Table 34 answers the question about the accuracy reached for the two survey procedures and for the different point types. We additionally mention:

- The standard absolute co-ordinate errors m_k are practically equal for all ten Restitution Centres. For the a-points the standard deviation amounts to hardly 1 µm and for the d-points to 4 µm.
- The standard absolute height errors m_z are also practically equal for all ten Restitution Centres. For the a-points the standard deviation amounts to only 1.5 µm and for the d-points to 4 µm.
- For the a-, c- and d-points the differences between the absolute errors and the relative errors and thus the systematic errors are in all cases significant. It is striking that also for the a-points such systematic deviations were unambiguously proven.
- For the b-points the variances agree in 75% of the cases. This is the effect of the low number of measurements.

We now calculate the influence of the survey procedure and the point type.

- Accuracy of the different survey procedures (V_A)
  We compare the standard errors of the terrestrial measurements with the different standard errors of the photogrammetric measurements. From table 34 we take the corresponding ratios V_A. Here

$$T : A : R : S = 1 : V_A(A) : V_A(R) : V_A(S)$$

  The ratios V_A are, of course, dependent on the photo scale. The value $V_A(A)$ for the standard co-ordinate errors m_k of the a-points amounts to $0.4 \cdot 10^{-3}$ m_b and for the g-points $0.8 \cdot 10^{-3}$ m_b. The corresponding values for the standard height errors m_z amount to $1.15 \cdot 10^{-3}$ m_b for the a-points as well as for the g-points. Because of the large differences in the accuracy of the terrestrial measurements the ratios V_A for the b- and c-points differ considerably from the average value.

For all points taken together

$$V_A(A) : V_A(R) : V_A(S) = 1.0 : 0.8 : 0.6.$$

- Accuracy of the different points types (V_P)
  As unit value we choose the standard error of the c-points. With respect to the terrestrial measurements, the standard errors m_k of the four point types are in the proportion of 0.75 : 1.70 : 1.00 : 1.25 and the standard errors m_z in the proportion of 0.70 : 2.40 : 1.00 : 1.40. Compiling the results of the non-signalised points we find that the standard errors m_k and m_z of the g-points are about 1.5 and 2.0 times as large as the corresponding errors of the a-points. Striking are the large errors for the b-points. But since the number of these points is very low the influence on the average value for the g-points is also very low.

  For the error values A, R and S the ratios V_P for m_k as well as for m_z are nearly equal. The co-ordinate errors m_k of the different point types are in the proportion of 0.25 : 1.30 : 1.00 : 0.95 : 0.60 and the standard height errors m_z in the proportion of 0.45 : 0.75 : 1.00 : 1.00 : 1.00. The standard errors m_k of the b-points thus are about 30% larger, those of the e-points (only relative errors) about 35% smaller than the corresponding errors of the c- and d-points. On the other side, the standard errors m_z of the b-points are 25% smaller than those for the c- and d-points. As to the rest the standard errors m_k and m_z of the g-points are about 3.5 and 2.3 times larger than the corresponding errors of the a-points. The influence of the transformation by means of the a-points on the accuracy of the g-points is without significance.

In order to calculate the influence of the other variables, namely photo scale, operator and position of the sun, on the accuracy we additionally compiled in table 35 the different ratios V_M, V_B and V_S of the standard absolute errors, separated according to parameters. In general the ratio figures for the error values A, R and S are nearly equal. The following results were obtained from our measurements:

- Accuracy for different photo scales (V_M)
  To the standard errors for the photo scale 1:6000 we assigned the value 1.00 each. For the photo scale 1:3500 the standard errors m_k of the a-points are about 20% and the standard errors m_z about 35% larger than for the scale 1:6000, while the standard errors of the g-points are by 5% and 20% larger than for the 1:6000 scale. The tendency thus is that the errors at a smaller scale are smaller. This is demonstrated best in the case of the a-points on the one side and in the case of the height errors on the other side. The ratios are, of course, reversed when errors in "cm in the terrain" are computed.

- Accuracy reached by different operators (V_B)
  To the standard errors of the 1st operator group we assigned the value 1.00 each. For the 2nd operator group the standard co-ordinate errors m_k and the standard height errors m_z for the a-points as well as for the g-points are somewhat larger than for the 1st operator group, but it is not to be seen why the errors should differ in size. In this connection we refer to the large systematic deviations and the somewhat smaller relative errors of the g-points on the part of the 2nd operator group. We also point out that the number of the operators as well as the number of the measurements differ for both groups. The differences between the standard errors of the two operator groups were at three Restitution Centres in 85% of the cases not significant, at another three Restitution Centres in 65% and at one Restitution Centre in 45% of the cases.

- Accuracy reached at different positions of the sun (V_S)
  To the standard errors for the flights in the morning we assigned the value 1.00 each. The standard errors are a little smaller for the afternoon flights than for the morning flights though but since the roof eaves lie under different azimuths it is not to be seen why the standard errors should be dependent on the azimuth of the sun. This does not preclude that there is for every single eave, depending on the position of the sun, another systematic displacement s, namely according to the equation:

$$s = a_o + a_1 \sin(\alpha + \alpha_o)$$

  For each Restitution Centre we calculated from the four restitutions each carried out by the same operator the mean values $'_o$, a_1' and s_o' as well as the deviations m_{ao}, m_{a1} and m_{so} of each single restitution of a Restitution Centre. s_o is the quadratic average of all s-values. The average of the values a_o', calculated from the absolute values, amounts to approximately 6.0 µm in the photograph. The deviation m_{ao} of the single values a_o amounts to 3.0 µm. The average of the values a_1', calculated from the absolute values, amounts to 5.5 µm in the image. The deviation m_{a1} of the single values a_1 is 5 µm. The average of the values s_o' amounts to 8.5 µm. The deviation of the ten values each attained at the <u>different</u> Restitution Centres amounts, however, to 8 µm for the a_o-values, to 3.5 µm for the a_1-values and to 4 µm for the s_o-values. These values are in part essentially larger than those obtained from the four values of the <u>same</u> Restitution Centre. This is a sign for a "personal" error of the single operators.

The influence of the azimuth α on s disappears when $\alpha = -\alpha_o \pm n \cdot 200^g$. Although the amplitudes a_1 only amount to about 6 µm and the standard deviation of α_o amounts to $\pm 45^g$, the azimuths α derived from the mean values $\alpha_{o,V}$ and $\alpha_{o,N}$ of the morning and afternoon flights agree nevertheless satisfactorily with the respective azimuth of the sun.

In the following we like to furnish some ideas on further investigations which are in part consequences of the error analysis. Some problems have been excluded from the test from the very beginning though, in order to avoid too large an extension of the programme.

1) The absolute errors, the relative errors and the systematic deviations are strongly correlated (see also [5]). It still should be investigated what influence this correlation has on the error analysis, in particular as far as the different types of points are concerned.
2) The differences between the absolute and relative errors are not very large and therefore of minor significance for the practice. Nevertheless we were in a position to significantly prove systematic deviations. In the case of the signalised a-points this can be inaccuracies of the terrestrial co-ordinates.

As far as the eaves are concerned (d-points), the position of the sun plays a role. It is still unclear, however, to what extent different grey values at the eaves and to what extent personal pointing errors of the operators are the reason for the systematic errors.

3) Our investigations on the systematic errors refer primarily to the co-ordinate errors m_k. But the Commission also discussed personal errors in the height pointing. In order to determine the varying accuracy at the various Restitution Centres, we converted the standard absolute deviations of the four restitutions 1, 3, 2 and 4 as well as 5, 7, 6 and 8 carried out by one operator into "μm in the image" and subsequently took the mean. Similarly we calculated, from the four photogrammetric height measurements of one operator as compared to the terrestrial mean value, the mean relative accuracy and the average of the systematic deviations. These investigations are still underway.

4) It is the analysis of the height pointing errors that would be particularly desirable since in the special case of building measurements, apart from the operator the type of the restitution instrument probably also plays a decisive role (comparators). The experiences gathered so far do not yet suffice to form an opinion.

5) It is imaginable that the location of the stations within the photogrammetric models influences the accuracy. For this reason the differences between the photogrammetric measurements and the terrestrial mean values were not merely compiled separately for Restitution Centres, restitutions and point types but also for groups of stations, namely the stations 11, 21, 31 ... 91 as well as 12, 22, 32 ... 92, etc. These investigations are still underway as well.

6) Whether the degree of accuracy reached suffices or not, must be decided from case to case. With respect to co-ordinate measurements it should be noted that the photo scale cannot be increased at will and that a certain error in identification may not go below a set limit. As far as graphic representations are concerned though, the map scale is of prime importance. For daily practice, however, any loss of points is at least as important as is the accuracy of the measurements since the economy of a photogrammetric procedure depends to a large degree on the extent of the terrestrial supplementary measurements. It is, for instance, striking that in particular building corners could hardly be surveyed photogrammetrically. How can the losses of points be reduced?

7.2 Comparison with Some Other Tests

In conclusion we compare our results with the results of some other tests as far as the results can be brought on a fairly comparable basis (see table 36). We confine ourselves to normal-angle photographs. Although the test of Dordrecht deals primarily with the measuring of building corners, roof corners and roof eaves, i.e. non-signalised points, we also include in the comparison the results obtained for signalised points in order to prove the reliability of our measurements.

The Oberriet photo material (primarily photographs on plates) was used for controlled tests by the International Society for Photogrammetry as well as by the OEEPE (see [7] and [8]. Contrary to Oberriet, a hilly, partially mountainuous area was chosen for the test field of Reichenbach (see [5]). The test of Vienna can in

part be considered an extension of the previous tests of Commission C towards larger photo scales. The models were restituted in analogue instruments as well as in stereocomparators. Apart from a camera RC 5a, 21/18 a camera RC 10, 30/23 was also used. As far as the results have already been published or are available they are included in this comparison (see [9] and [10]). In the test of Dordrecht the building points were measured in small partial areas, so-called stations, and their position with respect to signalised points was determined. For this reason the absolute error A is considerably smaller than in other tests. The absolute errors must more or less be taken as components of the relative error R.

There is only little information on the accuracy of non-signalised points. The literature published on photogrammetric building measurements was evaluated in an Invited Paper presented at the ISP Congress in Ottawa (see [1]). Here we do not concern ourselves in detail with these contributions but content ourselves with an average value for the accuracy (mean of 18 different investigations). Among them may also be some results for wide-angle photographs but that does not matter since in nearly all reports data on height errors are missing. In the meantime, the results of the "measurements at non-signalised points in the test area of Oberriet" have been published (see [11]). According to their recognizability, the points were divided into two groups, namely group B: building objects (roof gable, building and roof corners, manholes, transmission poles, and the like) and group P: corners of parcels. In each group distinctions were drawn between large photo scales (1:4700 - 1:6000) and smaller photo scales (1:8600 - 1:10.000). The results indicated in table 36 refer to the well identifiable B points (building objects). In the test of Vienna nine types of typical municipal detail points were distinguished. We confine ourselves to the building corners, house joints and front doors (groups 1 - 3). It would suggest itself to also include in the comparison the results obtained from the measurements of curbstone straights and curbstone curved portions (groups 4 and 5) but the standard deviations m_D cannot be compared directly with the co-ordinate errors. They would have to be combined first with the appertaining angular errors m_W. Therefore we dispense with these data. For the non-signalised points the absolute errors A are - for the same reason as for the signalised points - essentially smaller than in the other tests. Further comparisons can only be made upon the publication of all results of the Vienna test.

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The Most Important Notations

d	differences (mostly parallel displacements)
f	number of the degrees of freedom
i	number of the measurements or restitutions
m	standard errors (estimated values or mean square deviations)
n	number of points of a station
s	systematic deviation
s^2	variance
x, y, z	co-ordinates
x', y', z'	co-ordinates x, y, z referred to the centre of gravity
v	corrections or deviations as compared to mean values
q	co-ordinates x, y, z
α	azimuth
β	vertical angles of the d-lines
Δ	co-ordinate differences
A	absolute accuracy
M	measuring accuracy
R	relative accuracy
S	systematic deviations
T	terrestrial measurement
N	total number of points, measurements etc.
V	ratio figures of standard errors

- indices:

a, b, c	for a-, b-, or c-points
d, e	for d- and e-points or lines
k	co-ordinates x, y
p	determined photogrammetrically
q	co-ordinates x, y, z
s	constant (systematic) parts
t	determined terrestrially
z	heights
M	measurements
P	points
St	stations

- type of points:

a	signalised points
b	house corners
c	roof corners (measured directly)
d	points of a roof eave
e	points of a roof ridge
g	building points (b-, c-, d- and e-points)

- variable:

A	survey procedure
B	operator
M	photo scale
P	point type
S	position of the sun

List of Tables

Summary

On the Accuracy of Photogrammetric Measurements of Buildings (Report on the results of the test Dordrecht carried out by Commission C of the OEEPE)

1. Structure of the Test

The test deals with the accuracy with which elements of buildings, such as corners, roof eaves etc., can be determined with respect to the position of nearby signalised points. It does not deal with the absolute accuracy with which buildings can be determined photogrammetrically in the model. The test also discloses with what degree of accuracy the necessary terrestrial supplementary measurements were carried out. As test field served part of the town of Dordrecht in the Netherlands (see fig. 1). Over the entire area, evenly distributed, groups of interrelated points - so-called stations - were selected and surveyed. For this purpose the test field was divided into 9 x 9 subregions of approximately 100 m x 100 m and in each of these areas one "station" was chosen (see fig. 2). We distinguish five types of points, namely:

a-points: signalised points (on the ground)
b-points: building corners
c-points: roof corners
d-points: points at roof eaves
e-points: points on roof ridges (to be measured only photogrammetrically).

The a-points serve as link between the photogrammetric and the terrestrial measurements. Each station has about four or five of such signalised points (see fig. 3).

As is general practice when photographs are taken from city areas, the photographic coverage was carried out with a normal-angle camera, namely a RMK 21/18 equipped with a photographic lens Topar. In order to make the most of the extensive terrestrial work, the area was photographed at two scales, viz. 1:6000 and 1:3500. In consideration of the building density and the visibility of the signalised points, the flights were carried out in such a manner that the flight axes of the two strips at both scales coincide in position.

In general, photo flights are performed in sunny weather. For this reason it is possible that the illumination of the buildings influences the photogrammetric measurement. In order to detect an influence of the azimuthal change of the illumination direction, the area was covered twice at both scales, once in the morning and once in the afternoon (see table 1). The most important parameters for photogrammetric measurements thus are point type, photo scale and position of the sun.

2. Measurements

From the very beginning of the test a numerical restitution had been intended. In order to ensure that the differences between the terrestrial and the photogrammetric measurements can be determined with a satisfying degree of accuracy, the station points were to be measured once terrestrially by five different survey teams and once photogrammetrically by five different Restitution Centres.

If possible, in each Restitution Centre a second operator had to repeat part of the photogrammetric measurements. To begin with, for each station the points and straights to be measured were marked on enlarged aerial photographs 1:700 (see fig. 7). In order to guarantee the necessary uniform assignment of point numbers, the numbers were assigned during the first terrestrial measurement (see fig. 6). The terrestrial measurements also offered the possibility to test the suitability of different roof plummets (see fig. 8). Regrettably ten of the originally selected stations could not be used because buildings or signals had been destroyed prior to the flight or because signals were not visible on the aerial photographs.

Ten Restitution Centres participated in the photogrammetric measurements (see table 2). Altogether we dispose of the results of 2310 station measurements (see table 3). In order to guarantee the correct encoding and the completeness of the measurements, for each model and for each Restitution Centre a list of numbers of the points to be measured was drawn up. To reach a standardization of the measurements, the Restitution Centres had to observe certain rules, e.g. that the models at small scale had to be measured first. All Restitution Centres employed experienced operators well familiar with the instruments used. All of them unanimously agreed that the identification of the points at 1:6000 photo scale was bad and that for this reason a larger photo scale is to be preferred for practical work.

3. Computation of the Co-ordinates

The Commission discussed all details of the computing work, considering in particular the different possibilities of comparing straights (roof eaves). In setting up the computing programme it was assumed that for each station and for each restitution the terrestrially determined co-ordinates as well as the photogrammetrically measured co-ordinates were available in a uniform local network. For the terrestrial measurements, the 1st setup point of a station was, as a rule, selected as the co-ordinate origin of the local system. Since great importance was attached to exact terrestrial comparative measurements, these were not only carried out five times independently, viz. by 5 field teams, but it was also ensured that, by the inclusion of tolerances in the subsequent computations, measurements were not unnecessarily rejected (see table 4). However, because of rejected or omitted observations, we do not dispose of exactly five independent co-ordinate sets for every point. Altogether there are 3228 co-ordinate sets for 665 points.

In order to facilitate the work for the Pilot Centre, the Restitution Centres had to do part of the computing work. Here, too, precise rules had to be observed. In particular a linear conformal transformation of the model co-ordinates had to be carried out while using special control points. According to the minutes of the Restitution Centres 9% of the measurements were unusable, which was primarily caused by difficulties in identification and by large differences between the first and second series. The Pilot Centre received from every Restitution Centre the punched cards with the transformed co-ordinates, separated according to stations and point types. As for the roof-ridges no terrestrial comparative measurements are available, after the transformations the co-ordinates obtained from the five restitutions were simply averaged. These mean values define the final photo-

grammetric e-straight. Since the planimetric co-ordinates of the a-points of different stations had not been determined terrestrially in one uniform system - as was originally assumed - the original computing programme was modified and the terrestrial co-ordinates for each station and each restitution were, by means of the a-points, transformed into a "photogrammetric system", i.e. into a system whose x-axis runs parallel to the flight axes. In order to eliminate gross errors, the Pilot Centre again included some tolerances in the computations, dependent on the photo scale and dependent on the point type (see table 4). The numerous exceeded tolerances for the d-points (scale 1:3500) must primarily be attributed to the measurements of four particular models (see table 5). Unfortunately not every Restitution Centre was in a position to have the measurements repeated by a second operator. Nevertheless there is a total of 23 035 photogrammetric measurements for 2310 measured stations.

4. Accuracy of the Measurements (Error Computations)

4.1 The Accuracy of the Terrestrially Determined Co-ordinates (T)

The accuracy of the terrestrially determined co-ordinates of the a-, b-, and c-points was derived from the differences between the co-ordinates obtained from each single measurement and the co-ordinate mean of the maximally five measurements. For the d-points, however, we first averaged the co-ordinates of the maximally five d-points at the beginning and at the end of each d-straight. By means of these two centres of gravity the final d-straight is determined. Subsequently we transformed all d-points for each roof eave measured by each of the five field survey teams into a new orthogonal system (which is formed by the final d-straight and a plane perpendicular to this straight) and derived from the corresponding horizontal and vertical deviations the standard co-ordinate errors. To allow a comparison with the photogrammetric co-ordinates, we additionally calculated the standard errors of the mean obtained from the five measurements (see tables 6 and 7).

4.2 The Accuracy of the Photogrammetrically Determined Co-ordinates

As to the photogrammetrically determined co-ordinates we distinguish four types of errors (see fig. 9):

- Measuring accuracy M

  From the differences between series 1 and series 2 we computed the standard co-ordinate errors of the mean of two measurements (see tables 8 and 9).

- Absolute accuracy A

  From the differences between the photogrammetrically determined co-ordinates of each single measurement and the corresponding terrestrial mean values we obtained the standard errors of the absolute accuracy (see tables 10 and 11).

- Relative accuracy R

  In order to determine the deviations of the co-ordinates in repeated restitutions, we first averaged the co-ordinates of the five photogrammetric measurements of each point. From the deviations of the single values from the corresponding mean value we then obtained the mean relative accuracy. The relative accuracy of the photogrammetrically determined e-points was computed the same way as the accuracy of the terrestrially determined d-points.

  Considering that some stations are located in the overlapping zone of the two flight strips, we occasionally did not combine five but 2 x 5 = 10 measurements to a mean value (see table 12).

- Systematic deviations S

  From the differences between the mean value of the five photogrammetrically determined co-ordinates and the terrestrial co-ordinates of comparison we obtained the systematic deviation. For the d-points the mean values of the horizontal transversal deviations are identical with the systematic deviations (see table 13).

Between the error values m_A, m_R and m_S exists a simple mathematical connection (see equations 42.47 - 42.49).

5. Comparison of Different Standard Errors

The tables in chapter 4 already answer some of the questions of the test programme For the analysis we combine the results of the photogrammetric measurements, e.g. for the scale 1:6000 the results of the restitutions 1 and 3, etc. These combinations are in short referred to as restitutions 13, ... etc. (see tables 14, 15, 17 and 18). We also pile the standard errors for the b-, c-, d- and e-points, i.e. for the non-signalised building points (g-points) and compare them with the results for the a-points. In these cases we have not considered the standard errors for each of the four point types as being of equal weight so as to avoid giving the few b-points an overweight. In the different paragraphs we deal first with the standard co-ordinate errors m_k and then with the standard height errors m_z, in the sequence of the different parameters, namely: point type, image scale, operator, and position of the sun. We find, e.g., that, for the terrestrial measurements, the ratio of the standard error m_k of the signalised a-points to that of the non-signalised building points (g-points) is approximately 1.0 : 1.6. As to the absolute errors of the photogrammetric measurements, though, this ratio is 1.0 : 3.2.

Table 10 contains the standard absolute deviations for each single Restitution Centre. We therefore investigate the dispersion of these values but restrict ourselves to the a- and d-points. The ratio of maximum value to minimum value normally lies between V = 1.5 and 3.0. In practice, however, one will probably mind less if, for the scale 1:6000, the m_k-values of the a-points fluctuate between 2 cm and 4 cm as if these values fluctuate between 6 cm and 16 cm for the d-points. To determine the varying accuracy at the Restitution Centres, we averaged the standard deviations of the four restitutions 1, 3, 2, and 4 and 5, 7, 6, and 8, each of one operator. At the same time we computed the standard deviations of these mean values (see table 16 and fig. 10).

In order to find out whether the differences between the absolute errors A and the relative errors R are statistically significant, i.e. whether systematic deviations are really available, we tested the different variances according to Fisher. While for the a-, c- and d-points the differences between the absolute and relative errors are significant, for the b-points the number of measurements is too low to obtain correct values for m_A and m_R and thus be able to determine significant differences (see table 19).

6. Analysis of the Standard Errors

6.1 The Accuracy of the Different Survey Procedures (V_A)

We compare the standard errors of the terrestrial measurements with the different errors of the photogrammetric measurements (see tables 20 and 21). To the terrestrial measurement we assigned the figure 1.0. Thus

$$T : A : R : S = 1 : V_A(A) : V_A(R) : V_A(S)$$

To eliminate the influence of the image scale, we converted the standard errors of the photogrammetric measurements to the scale 1:1000 and averaged the V_A-values. We found, e.g.:

- The value $V_A(A)$ for the standard absolute co-ordinate error m_k of the a-points is $0.40 \cdot 10^{-3}\ m_b$, for the non-signalised g-points, however, $0.80 \cdot 10^{-3}\ m_b$.

  The corresponding value $V_A(A)$ for the standard height errors m_z is for the a-points as well as for the g-points $1.15\ 10^{-3}\ m_b$. Striking is the small value for the b-points and the large value for the d-points.
- For all point types together

$$V_A(A) : V_A(R) : V_A(S) = 1.0 : 0.8 : 0.6.$$

6.2 The Accuracy of the Different Types of Points (V_P)

Each station comprises an area of only 100 m x 100 m. Within so small an area a number of systematic influences, e.g. caused by distorsion, are constant and are eliminated by the transformation. The standard co-ordinate error of the a-points is with $m_k = 5.5$ µm very small (table 15). We may thus infer that at the time our photogrammetric measurements were taken, the conditions were not particularly unfavourable. The standard co-ordinate errors m_k of the different point types are in the proportion of approximately 0.25 : 1.30 : 1.00 : 0.95 : 0.65 (table 22). In this connection we assigned to the error of the c-points the figure 1.0. The standard co-ordinate errors of the b-points are about 30% larger than those of the c-points. The number of the b-points is very low though. Already at the time of the reconnaissance we realised that it is very difficult to find in a densely built-up area house corners which are visible from the air. For the e-points, only relative errors are available. But since it is not likely that the systematic deviations for the roof ridges are larger than those for the roof eaves, it is to be assumed that the absolute errors of the e-points as well are correspondingly smaller than those of the d-points. The standard height errors m_z of the different point types are in the proportion of 0.45 : 0.75 : 1.00 : 1.00 : 1.00. This means that the standard errors m_z of the b-points are smaller than those of the c-points. The reason for this may be that the b-points are primarily ground points. The standard errors m_z of the c-, d- and e-points are practically equal. The influence

of the transformation by means of the a-points on the calculated accuracy values of the non-signalised points is practically without significance.

6.3 Accuracy at Different Photo Scales (V_M)

For the error types A, R, and S we obtain with a smaller scale (1:6000) smaller errors than with a larger scale (1:3500) (see table 23). The ratios are, of course, reversed when we calculate with errors in "cm in the terrain".

6.4 Accuracy Obtained by Different Operators (V_B)

For the error types A, R, and S the standard co-ordinate errors m_k of the a-points as well as those of the non-signalised g-points are for the second operator group 10% larger than for the first operator group, i.e. they are practically equal (see table 24). On the other side, for the second operator group the g-points have larger systematic deviations but smaller relative errors. As to the standard height errors m_z the proportions are similar. The significance of the differences was tested once with the t-test according to Student and once with the F-test according to Fisher (see tables 25 and 26). From this results that at some Restitution Centres the results obtained by the two operators are also significantly different (see tables 27 and 28). It should also be mentioned that the results of the two tests do not agree in all instances.

6.5 Accuracy at Different Positions of the Sun (V_S)

In the course of the test the influence of the azimuthal change of the illumination direction was to be determined. For this purpose for each photo scale two flights were carried out at different times of the day. The standard errors m_k of the afternoon flights are nearly 10% smaller than those of the morning flights. However, considering that the roof eaves lie under different azimuths it is not to be seen why the standard errors are supposed to be dependent on the azimuth of the sun (table 29). This does not preclude, however, that, depending on the position of the sun, there is a systematic displacement s for every single roof eave. If we graph these s-values of the single measurements taken by each Restitution Centre as a function of the azimuth (see fig. 12), it becomes clearly visible that, on the one side, there is a preferred building direction in the test area and that, on the other side, the dependence of the s-values on the azimuth differs in all measurements. In order to analyse this dependence we calculated - by means of the method of least squares - for each measurement a simple sine curve according to equation 65.01 (see table 30 and fig. 13). a_o is a constant personal measuring error on the part of the operator. a_1 is the amplitude of the influence depending on the azimuth of the roof eave and α_o is a phase shift which is connected with the azimuth of the sun at the time of the photographic coverage. From a_o and a_1 we first calculated the quadratic average s_o of s (accord. to equation 65.02) and then the average values $\bar{a}_o$, $\bar{a}_1$, $\bar{s}_o$, and $\bar{\alpha}_o$ for each restitution (see table 31). In order to ascertain the differences at the single Restitution Centres, we additionally converted the values a_o, a_1, and s_o of the four restitutions of one operator by means of the scale denominator into "µm in the image" and subsequently averaged the values. Apart from these mean values a_o', a_1', and s_o' we calculated the deviations m_{ao}, m_{a1}, and m_{so} of each single measurement of one operator (see table 32 and fig. 14). We found:

- The mean values a_o' lie between - 18 μm and + 7 μm. The average of all ten values, absolutely calculated, amounts to 6 μm in the image. The deviation m_{ao} of the single values a_o amounts to 3 μm.
- The mean values a_1' lie between - 3 μm and + 9 μm. The average of all ten mean values, absolutely calculated, amounts to approximately 5.5 μm in the image. The deviation m_{a1} of the single values a_1 amounts to 5 μm.
- The mean values s_o' lie between 5 μm and 19 μm. The average of all ten values amounts to 8.5 μm in the image. The deviation m_{so} of the single values s_o amounts to 3 μm.

Striking is the large value 18 μm for a_o' and thus the correspondingly large value 19 μm for s_o'. The dispersions of the mean values a_o' and s_o' obtained from the deviations of these values as compared to the overall mean $\bar{a}_o$, $\bar{a}_1$ and $\bar{s}_o$ of the ten d i f f e r e n t Restitution Centres are considerably larger (see tables 31 and 32). This means that the personal error of one operator during the four different restitutions was equal. But apart from the operators whose personal errors are very small, there are operators with relatively large personal errors.

Finally we computed the average values $\alpha_{o,V}$ and $\alpha_{o,N}$ of the "phase shift" α_o for the flights in the morning and in the afternoon. The influence of the azimuth on s disappears when

$$a = - \alpha_o \pm 200^g$$

We found the values $\alpha_{o,V} = 72^g$ and $\alpha_{o,N} = 354^g$ and obtain from this as azimuth of the sun

- for the morning flights: $\alpha_V = 128^g$
- for the afternoon flights: $\alpha = 246^g$

From the flight data resulted, however:

- for the morning flights: $\alpha_V = 133^g$
- for the afternoon flights: $\alpha_N = 252^g$

Considering that the amplitudes a_1 are, on an average, only about 6.5 μm and that the deviation of the single values α_o amounts to about 45^g, the agreement between the values α_V and α_N is truly sufficient.

7. Result

In table 34 we have once more combined part of the errors discussed in chapters 4 and 5 to obtain a better overall view. We first distinguish the following variables:

- Survey procedures. (As to the photogrammetric measurements we differentiate in addition between measuring accuracy M, absolute accuracy A, relative accuracy R, and systematic deviations S.)

- Co-ordinate errors m_k and height errors m_z, viz. for the terrestrial measurements in "cm in the terrain", for the photogrammetric measurements in "μm in the image".
- Type of point.

The last column shows the ratio of the standard errors of the non-signalised points (g-points) to those of the signalised points (a-points).

In order to calculate the influence of the other variables, namely photo scale, operator and position of the sun, on the accuracy we compiled in table 35 the different ratios V_M, V_B, and V_S of the standard absolute errors. In general, the ratio figures for the error values A, R, and S are nearly equal.

Finally we compare our results with the results obtained from some other tests as far as they can be put on a fairly comparable basis (see table 36). In doing so we restrict ourselves to normal-angle photographs.

In conclusion we furnish a few ideas regarding further investigations which emerge in part from the error analysis. Some problems had, however, been excluded from the test from the beginning in order to prevent too great an extension of the programme.

Annex

with 36 tables

Table 1 - Further data of the photo flights

Photo scale	Time of photograph	Time of exposure [s]	Overlap in %	
			transversal	lateral
1:6 000	in the morning	1/250	65	80
1:6 000	in the afternoon	1/525	65	80
1:3 500	in the morning	1/250	30	80
1:3 500	in the afternoon	1/450	30	80

Table 2 - Restitution Centres and some data on the photogrammetric restitutions

	Restitution Centre	Restitution instruments	Correction plates	Measuring mark	Model scale m_b = 1 :		Number of models measured		Hours/Model m_b = 1 :	
					6000	3500	1^{st} oper.	2^{nd} oper.	6000	3500
0	Bundesamt für Eich- und Vermessungswesen, Wien	A7	no	point mark ø 0.01 mm with ring	1 : 3000	1 : 1750	14	6	17.8	7.8
1	afd. Geodesie, Technische Hogeschool, Delft	A10	no	black point ø 0.04 mm	1 : 3000	1 : 1750	14	-	8	4
2	Geodätisches Institut Technische Hochschule, Aachen	C8	yes	luminous mark ø 0.08 mm	1 : 2500	1 : 5000	14	-	20	8
3	Institut für Geodäsie und Photogrammetrie Eidgenössische Technische Hochschule, Zürich	STK 1	not applicable	point mark ø 0.02 mm with ring	-	-	14	-	7	3.4
4	Institut de Photogrammétrie, Ecole Polytechnique Fédérale, Lausanne	A8	no	black point ø 0.06 mm	1 : 3750	1 : 2500	14	6	10	

Table 2 - Restitution Centres and some data on the photogrammetric restitutions (Continuation)

	Restitution Centre	Restitution instruments	Correction plates	Measuring mark	Model scale m_b = 1 :		Number of models measured		Hours/Model m_b = 1 :	
					6000	3500	1^{st} oper.	2^{nd} oper.	6000	3500
5	International Institute for Aerial Survey and Earth Sciences, Enschede	AP/C	not applicable	-	-	-	12	6	-	-
6	Institut für Angewandte Geodäsie, Frankfurt	Planimat	no	luminous mark ø 0.04 mm	1 : 2580	1 : 1480	12	6	10.8	5.5
7	Landesvermessungsamt Nordrhein-Westfalen, Bad Godesberg	A7	no	point mark ø 0.14 mm	1 : 2600 to 1 : 3000	1 : 1500 to 1 : 1700	12	6	5.7	
8	Landesvermessungsamt Rheinland-Pfalz, Koblenz	C8	yes	cross mark	1 : 2500	1 : 1500	12	6	15	8
9	Luftbild- und Rechenstelle der Landeskulturverwaltung Rheinland-Pfalz Mainz	C8	yes	cross mark	1 : 2500	1 : 2000	12	5	8	6

Table 3 - List of the photogrammetric measurements
Number of stations measured

Restitution Centre	Operator	1st operator				2nd operator				Total number of stations measured
	Photo scale	1:6 000		1:3 500		1:6 000		1:3 500		
	Time of photograph	in the morning	in the afternoon	in the morning	in the afternoon	in the morning	in the afternoon	in the morning	in the afternoon	
	Restitution	1	3	2	4	5	7	6	8	
0	Flight strip 1	50	53	33	39	24	25	18	17	259
1		50	53	37	39	-	-	-	-	179
2		50	53	37	39	-	-	-	-	179
3		50	53	36	39	-	-	-	-	178
4		50	53	37	39	24	25	18	17	263
5	Flight strip 2	34	53	35	42	23	29	19	20	255
6		34	53	35	42	23	29	19	23	258
7		34	53	35	42	23	29	19	23	258
8		34	53	35	42	23	29	19	23	258
9		34	53	35	42	-	29	19	11	223
Total number of stations measured		420	530	355	405	140	195	131	134	2 310

Table 4 - List of the tolerances in the search for gross errors in "centimetres"

Point type	Terrestrial measurements				Photogrammetric measurements			
	Differences between two measurements		Deviations as compared to the mean value		Deviations as compared to the mean value			
					1:6 000		1:3 500	
	x,y	z	x,y	z	x,y	z	x,y	z
a	30	40	10	10	15	45	15	35
b	30	40	15	15	50	75	25	50
c	30	40	15	15	50	75	25	50
d	30	40	15	15	50	75	25	50
e	-	-	-	-	20	40	12	24

Table 5 - List of the values which exceeded the tolerances for the photogrammetric measurements

Point type	1:6 000 Restitutions 1,3,5 and 7				1:3 500 Restitutions 2,4,6 and 8			
	n_1	n_2	Δn	Δn%	n_1	n_2	Δn	Δn%
a	4 272	4 264	8	0.2	3 606	3 584	22	0.6
b	103	100	3	2.9	174	163	11	6.3
c	1 381	1 357	24	1.7	1 220	1 174	46	3.8
d	5 344	5 171	173	3.2	4 520	4 239	281	6.2
e	1 346	1 310	36	2,7	1 069	1 038	31	2.9
a-e	12 446	12 202	244	2.0	10 589	10 198	391	3.7

n_1 = Total number of measurements

n_2 = Measurements used

$\Delta n = n_1 - n_2$ = Omissions

Table 6 - Accuracy of the co-ordinates determined terrestrially (chapter 4.1)

Point type	N_M	N_p	m_k cm	m_z cm	M_k cm	M_z cm
a	1 250	261	1.3	1.3	0.6	0.6
b	114	23	2.9	4.6	1.3	2.0
c	390	81	1.7	1.9	0.8	0.8
d	1 474	300	2.1	2.7	0.9	1.2
g	1 978	404	2.1	2.7	0.9	1.2

N_M = Number of measurements

N_p = Number of points

m = Standard error of a measurement

M = Standard error of the mean obtained from five measurements

g = Building points (b-, c- and d-points)

Table 7 - Distribution of the differences existing between the co-ordinates of each single terrestrial measurement and the co-ordinate means of all i-measurements (chapter 4.1)

Differences in cm		-point type										
		a-			b-			c-			d-	
from	to	x	y	z	x	y	z	x	y	z	y	z
-16	-15											
-15	-14					2						
-14	-13						1				1	2
-13	-12											1
-12	-11									1		
-11	-10										2	1
-10	- 9						2				2	3
- 9	- 8					1	2		1		2	2
- 8	- 7									1	3	6
- 7	- 6			1	1	3	2	2	1	1	4	10
- 6	- 5		1	1	2		3		1	1	7	12
- 5	- 4	1	2	1			3	3	2	1	9	18
- 4	- 3	1	4	3	1	3	5	7	3	3	29	39
- 3	- 2	19	19	20	3	5	13	12	17	12	68	66
- 2	- 1	84	78	68	12	13	15	42	44	50	215	189
- 1	0	514	511	505	38	29	8	126	122	144	399	411
0	1	533	531	551	38	21	20	130	118	102	389	406
1	2	78	82	68	11	19	13	47	56	41	200	137
2	3	12	15	18	4	9	10	12	17	21	91	74
3	4	5	5	1	3	2	4	5	2	2	27	31
4	5	2	2	3		2	1	1	2	8	9	24
5	6	1		4		2	3		2		3	9
6	7			3			3		1	1	7	9
7	8				1		3	1	1	1		6
8	9					1		1			4	4
9	10					1	1				2	4
10	11					1		1			1	2
11	12											5
12	13						1					1
13	14											1
14	15						1					1
15	16											

M 1

Table 8 - Measuring accuracy (M1)
Standard errors of the mean obtained from two measurements in "cm in the terrain" (chapter 4.2.1)

Restitution	Restitution Centre	a - points			b - points			c - points		
		N_p	m_k	m_z	N_p	m_k	m_z	N_p	m_k	m_z
1*)	1	181	1.8	8.4	5	3.9	7.8	55	3.9	9.5
	2	189	2.1	5.7	5	3.3	7.8	55	2.5	5.8
	3	177	0.9	-	5	3.2	-	51	2.2	-
	4	189	2.6	3.5	5	7.7	5.4	54	3.9	5.1
	5	126	1.9	5.2	2	1.2	4.0	34	3.0	6.8
	6	131	2.0	4.8	1	2.9	2.6	34	2.1	5.4
	7	135	1.9	3.9	-	-	-	33	2.8	9.7
	8	128	2.1	5.5	1	4.0	1.3	34	3.8	8.0
	9	134	1.4	4.4	2	2.7	4.4	34	2.4	7.5
3	1	183	1.6	3.9	3	3.3	5.7	57	3.6	5.9
	2	191	3.1	5.4	3	2.2	5.0	57	4.2	4.8
	3	174	0.8	-	3	3.3	-	56	2.2	-
	4	189	2.4	3.8	3	1.7	5.0	52	3.4	5.2
	5	190	1.7	5.2	5	4.4	2.4	61	2.9	5.6
	6	196	1.9	1.9	6	1.5	2.4	62	2.2	1.8
	7	203	1.8	5.9	5	3.5	6.4	60	3.0	8.0
	8	201	2.0	4.2	5	3.3	12.5	62	2.9	6.6
	9	201	2.1	9.0	6	2.3	12.3	62	2.3	9.4
5	4	98	2.4	2.8	1	3.0	1.9	32	2.7	3.6
	5	78	1.6	3.9	1	0.5	11.5	19	3.9	6.6
	6	75	3.2	4.1	1	4.0	1.3	20	3.9	4.8
	7	84	1.1	4.4	-	-	-	20	2.1	6.8
	8	84	2.6	5.3	1	0.8	10.0	19	6.3	14.3
	9	-	-	-	-	-	-	-	-	-
7	4	93	2.1	2.6	1	4.8	7.5	33	3.0	3.4
	5	96	1.4	4.9	3	3.5	5.7	26	2.6	7.8
	6	101	3.0	3.1	4	10.0	1.7	28	3.1	3.9
	7	105	1.2	4.3	4	7.3	1.5	28	2.2	4.5
	8	104	2.5	6.0	4	4.7	10.2	25	4.1	11.5
	9	105	1.8	6.7	4	3.8	9.4	28	4.1	8.0

M 1

Table 8 (Continuation)

Restitution	Restitution Centre	a - points N_p	m_k	m_z	b - points N_p	m_k	m_z	c - points N_p	m_k	m_z
2	1	140	0.8	2.4	7	2.8	3.1	39	1.6	3.7
	2	157	1.1	3.0	6	2.1	2.7	39	1.4	3.1
	3	132	0.6	-	5	3.9	-	38	1.5	-
	4	156	1.0	2.2	7	3.3	2.6	39	2.0	2.9
	5	119	0.8	3.1	4	1.1	3.0	47	1.9	3.6
	6	130	1.0	1.3	4	1.9	0.6	47	1.3	1.7
	7	137	0.9	2.8	2	1.8	1.2	46	1.7	5.1
	8	134	0.9	2.8	4	1.3	1.7	47	1.5	4.1
	9	134	1.1	4.3	4	1.8	4.0	47	1.9	5.5
4	1	152	0.8	2.2	7	3.3	1.8	43	1.4	3.4
	2	177	1.2	3.2	6	4.5	3.8	43	1.6	3.9
	3	146	0.6	-	6	5.3	-	37	1.3	-
	4	164	1.0	2.4	7	3.8	3.7	43	2.1	2.4
	5	148	0.8	3.5	7	2.7	2.5	51	1.5	3.5
	6	173	1.0	1.1	7	1.5	1.3	51	1.2	1.0
	7	175	1.0	2.8	6	1.7	3.3	50	1.6	4.6
	8	174	1.0	3.1	7	1.6	2.8	51	1.4	4.0
	9	176	1.4	3.1	7	1.7	5.0	51	1.8	5.0
6	4	75	0.9	1.8	3	2.5	1.6	24	2.1	1.8
	5	62	0.9	2.6	3	2.2	2.3	25	2.0	4.3
	6	69	1.4	1.7	2	1.4	1.8	24	2.1	4.6
	7	72	0.9	2.5	2	1.0	8.9	25	1.4	3.9
	8	72	1.4	3.4	3	1.8	3.3	25	3.5	11.1
	9	72	1.4	6.6	3	4.5	3.7	25	2.2	8.5
8	4	72	0.8	2.1	3	2.9	1.2	23	1.6	3.4
	5	87	0.7	2.3	6	2.1	1.9	24	2.0	2.8
	6	95	1.3	1.8	6	1.3	2.1	24	2.4	2.1
	7	95	0.9	2.9	6	2.7	3.2	24	1.5	3.4
	8	95	1.5	3.1	6	2.3	5.0	24	1.9	3.4
	9	48	1.6	5.8	2	3.0	9.2	15	2.4	7.9

N_p = Number of points measured (differences)
m_k = Standard co-ordinate measuring error of the mean obtained from two series
m_z = Standard height error of the mean obtained from two series
x) see table 3

M 2

Table 9 - Measuring accuracy (M 2)
Compilation according to restitutions (chapter 4.2.1)

Restitution	a - points N_M	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	b - points N_M	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	c - points N_M	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	g - points N_M	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
1x)	1390	1.9	5.5	3.2	9.2	26	4.5	6.3	7.5	10.5	384	3.1	7.4	5.2	12.3	410	3.2	7.3	5.4	12.2
3	1728	2.0	5.4	3.3	9.0	39	3.0	7.8	5.0	13.0	529	3.0	6.3	5.0	10.5	568	3.0	6.4	5.0	10.7
2	1239	0.9	2.8	2.6	8.0	43	2.6	2.7	7.4	7.7	389	1.7	3.9	4.9	11.1	432	1.8	3.8	5.2	10.8
4	1485	1.0	2.8	2.9	8.0	60	3.1	3.2	8.9	9.1	420	1.6	3.7	4.6	10.6	480	1.9	3.6	5.3	10.4
5	419	2.3	4.2	3.8	7.0	4	2.5	7.7	4.2	12.8	110	3.9	7.7	6.5	12.8	114	3.9	7.7	6.4	12.8
7	604	2.1	4.9	3.5	8.2	20	6.4	6.9	10.7	11.5	168	3.3	6.9	5.5	11.5	188	3.8	6.9	6.3	11.5
6	422	1.2	3.5	3.4	10.0	16	2.6	4.0	7.4	11.4	148	2.3	6.5	6.6	18.6	164	2.3	6.3	6.7	18.0
8	492	1.2	3.0	3.4	8.6	29	2.3	3.9	6.6	11.1	134	2.0	3.9	5.7	11.1	163	2.1	3.9	5.9	11.1

N_M = Number of double measurements (differences)
x) = see table 3

A 1

Table 10 - Absolute accuracy (A1)

Standard deviations obtained from the differences between the photogrammetrically determined co-ordinates and the terrestrial mean values in "cm in the terrain" (chapter 4.2.2)

Restitution	Restitution Centre	a - points			b - points			c - points			d - points		
		N_p	m_k	m_z	N_p	m_k	m_z	N_p	m_k	m_z	N_p	m_k	m_z
1 x)	0	167	2.2	9.4	5	14.8	13.4	53	9.3	19.0	207	6.9	15.6
	1	167	2.3	9.2	5	17.9	9.6	54	9.0	21.2	208	8.7	16.1
	2	167	4.2	10.7	5	15.3	16.2	53	9.0	22.0	207	8.9	17.4
	3	166	2.2	8.2	5	12.1	17.7	55	13.0	22.8	199	11.7	20.6
	4	167	3.9	9.5	5	16.8	8.7	55	11.3	17.7	208	9.2	19.8
	5	116	2.2	6.9	2	11.1	14.9	34	5.5	13.0	130	6.7	14.5
	6	110	3.0	6.7	1	12.0	0.8	32	16.8	17.1	117	16.1	18.2
	7	116	2.7	6.3	2	13.7	14.5	33	12.3	21.8	124	9.9	17.8
	8	111	3.0	7.0	1	2.3	8.4	33	10.6	15.1	127	10.2	20.4
	9	114	2.7	7.8	2	15.3	1.4	32	14.3	22.1	117	14.9	23.4
3	0	168	2.2	5.5	3	4.5	10.7	56	7.6	11.8	214	7.5	13.9
	1	171	2.5	6.4	3	5.6	5.5	56	8.2	13.1	217	7.9	18.0
	2	171	4.1	8.7	3	9.4	7.9	57	8.6	10.7	214	8.8	14.6
	3	167	2.2	5.4	3	6.4	12.0	57	13.1	13.2	205	10.1	15.1
	4	171	3.5	6.3	3	6.0	8.2	57	11.0	13.4	218	8.9	11.9
	5	181	2.2	7.2	5	14.6	9.1	62	6.2	10.2	234	6.3	12.6
	6	172	3.5	7.8	6	12.5	12.6	58	14.8	15.5	224	14.6	19.6
	7	185	2.7	6.4	4	15.2	8.7	60	12.8	25.3	229	8.1	20.0
	8	182	3.6	8.1	5	9.9	18.9	62	9.7	18.6	236	8.8	20.6
	9	182	2.6	8.6	6	12.9	15.7	62	12.2	19.6	217	10.6	20.3
5	0	88	2.1	9.9	1	9.9	5.9	30	8.2	20.0	104	8.6	20.6
	4	88	3.1	5.7	1	16.8	7.0	32	8.6	9.6	110	9.0	11.7
	5	74	2.5	5.6	1	7.0	14.7	17	13.8	17.1	75	9.6	22.2
	6	66	3.6	5.0	1	3.6	3.1	18	19.6	15.8	64	15.5	23.5
	7	76	2.2	6.4	1	7.3	20.3	19	10.3	12.5	78	10.6	13.3
	8	76	4.1	7.2	1	5.9	2.5	19	13.4	35.8	74	9.9	32.0
	9	-	-	-	-	-	-	-	-	-	-	-	-
7	0	84	2.8	7.6	1	2.8	1.9	32	6.9	14.0	112	5.1	12.3
	4	84	3.1	6.1	1	1.7	1.7	33	9.4	12.0	116	8.2	14.2
	5	94	2.4	7.2	3	14.0	10.1	27	16.4	14.9	118	12.1	18.6
	6	93	4.2	7.6	3	16.0	8.1	28	13.8	13.6	117	12.6	15.2
	7	97	2.0	7.2	4	16.5	7.0	28	9.3	8.7	122	8.5	17.7
	8	96	4.0	8.0	4	17.1	34.3	25	11.2	28.1	113	10.7	30.1
	9	97	2.4	8.8	4	11.4	21.0	28	10.3	13.8	116	9.4	20.4

A 1

Table 10 - (Continuation)

Restitution	Restitution Centre	a - points			b - points			c - points			d - points		
		N_p	m_k	m_z	N_p	m_k	m_z	N_p	m_k	m_z	N_p	m_k	m_z
2	0	124	1.9	7.7	6	8.0	11.6	33	5.8	10.2	127	5.2	12.4
	1	133	1.9	4.8	7	13.2	8.1	39	4.7	8.8	160	5.8	10.4
	2	132	2.3	6.6	7	9.5	8.2	39	5.3	11.5	159	6.4	12.2
	3	129	2.2	6.2	4	12.4	11.7	37	6.6	11.5	139	5.8	16.8
	4	133	1.7	4.3	6	11.4	5.1	38	5.8	10.2	164	5.6	10.1
	5	111	1.8	6.8	4	5.9	8.6	37	4.6	20.1	113	4.5	17.4
	6	106	2.1	5.5	4	11.4	10.3	47	8.0	12.1	142	8.8	13.6
	7	113	1.7	5.6	3	1.2	6.6	46	6.5	16.0	146	6.1	12.9
	8	111	2.1	5.3	4	5.5	7.6	46	5.5	12.0	150	6.6	12.8
	9	110	2.3	7.1	4	5.0	8.5	45	5.9	14.0	144	6.4	17.5
4	0	144	2.2	6.8	6	5.7	8.2	42	7.4	10.6	166	6.3	14.0
	1	143	1.9	5.0	6	7.4	4.7	43	6.3	12.8	169	5.8	10.5
	2	144	2.4	6.6	7	10.7	8.8	43	5.2	9.9	169	4.6	8.2
	3	140	2.2	5.3	6	8.4	6.0	40	8.7	9.5	157	6.6	11.8
	4	143	2.1	4.3	6	8.0	5.2	43	8.4	10.4	170	6.2	9.7
	5	147	1.8	5.4	7	6.7	6.2	51	4.0	9.4	176	4.1	8.0
	6	145	2.0	7.7	7	6.6	6.3	49	6.0	7.8	166	9.3	10.1
	7	149	1.7	5.8	7	6.4	7.4	50	6.3	13.7	176	4.2	11.3
	8	147	2.4	6.8	7	8.2	12.3	51	5.0	11.3	178	4.9	12.2
	9	147	2.2	6.8	7	4.8	14.2	50	6.7	14.8	173	5.7	14.6
6	0	67	1.5	4.8	3	7.8	12.1	22	5.3	13.7	86	5.6	11.8
	4	67	1.8	5.2	3	12.0	5.8	22	5.7	7.5	88	5.8	7.2
	5	59	1.2	5.7	3	6.4	8.4	24	6.5	20.1	81	7.4	21.6
	6	58	2.1	4.0	2	7.3	8.0	23	9.1	10.9	77	8.8	8.7
	7	61	1.8	5.4	3	2.3	5.7	25	5.7	8.0	81	5.7	9.5
	8	61	2.7	6.0	3	7.7	10.6	25	6.8	17.4	79	7.0	17.0
	9	61	2.6	7.3	3	9.3	17.1	23	7.5	17.3	81	6.4	16.9
8	0	68	3.0	8.9	3	3.9	8.2	23	8.8	15.3	84	6.6	16.9
	4	68	2.4	4.8	3	5.4	3.0	23	8.8	6.7	86	6.8	8.8
	5	76	3.1	11.8	3	2.2	1.9	10	9.2	38.2	25	10.2	37.7
	6	80	2.2	4.2	5	9.0	5.9	22	10.2	8.2	83	8.8	10.3
	7	83	1.9	6.0	6	7.2	12.9	24	6.5	9.7	95	4.6	8.4
	8	83	2.6	6.7	6	10.5	22.6	24	6.8	13.3	95	5.7	14.1
	9	42	2.3	7.0	2	2.5	4.5	15	4.7	6.4	53	4.8	10.2

N_p = Number of points (differences)

x) see table 3

Table 11 - Absolute accuracy (A 2)
Compilation according to restitutions (chapter 4.2.2)

Restitution	a - points					b - points				
	N_M	m_k	m_z	m_k	m_z	N_M	m_k	m_z	m_k	m_z
		cm	cm	µm	µm		cm	cm	µm	µm
1x)	1401	3.0	8.5	5.0	14.2	33	14.8	13.0	24.7	21.7
3	1750	3.0	7.3	5.0	12.2	41	11.1	12.3	18.5	20.5
2	1201	2.1	6.1	6.0	17.4	49	9.6	8.8	27.4	25.1
4	1449	2.1	6.1	6.0	17.4	66	7.5	8.6	21.4	24.6
5	468	3.0	6.9	5.0	11.5	6	9.4	11.0	15.7	18.3
7	645	3.0	8.1	5.0	13.5	20	14.2	19.2	23.7	32.0
6	434	2.1	5.5	6.0	15.7	20	8.1	10.5	23.1	30.0
8	500	2.5	7.5	7.1	21.4	28	7.4	12.7	21.1	36.3

Restitution	c - points				
	N_M	m_k	m_z	m_k	m_z
		cm	cm	µm	µm
1x)	434	11.2	19.7	18.7	32.8
3	587	10.8	15.5	18.0	25.8
2	407	6.0	12.8	17.1	36.6
4	462	6.4	10.9	18.3	31.1
5	135	12.2	17.2	20.3	28.7
7	201	11.3	14.7	18.8	24.5
6	164	6.8	13.5	19.4	38.6
8	141	8.1	13.2	23.1	37.7

Table 11 - (Continuation)

Restitution	d - points					g - points				
	N_M	m_k	m_z	m_k	m_z	N_M	m_k	m_z	m_k	m_z
		cm	cm	µm	µm		cm	cm	µm	µm
1x)	1644	10.3	17.5	17.2	29.2	2111	10.6	17.9	17.7	29.9
3	2208	9.4	16.5	15.7	27.5	2836	9.7	16.2	16.2	27.1
2	1444	6.3	13.2	18.0	37.7	1900	6.3	13.0	18.1	37.2
4	1700	5.9	10.3	16.9	29.4	2228	6.0	10.4	17.3	29.6
5	505	10.4	18.7	17.3	31.2	646	10.8	18.3	18.0	30.6
7	814	9.8	18.6	16.3	31.0	1035	10.2	17.9	17.0	29.9
6	573	6.7	13.3	19.1	38.0	757	6.8	13.3	19.3	37.9
8	522	6.6	12.6	18.9	36.0	691	7.0	12.7	19.9	36.4

N_M = Number of measurements

x) see table 3

Table 12 - Relative accuracy (R2)
Standard errors obtained from the differences between the photogrammetrically determined co-ordinates and the corresponding photogrammetric mean values.
Compilation according to restitutions (chapter 4.2.3)

Restitution	a-points						b-points						c-points					
	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
1 x)	1401	194	2.0	6.1	3.3	10.2	33	6	12.2	11.5	20.3	19.2	434	62	9.1	17.7	15.2	29.5
3	1750	231	2.2	5.7	3.7	9.5	41	8	10.5	12.2	17.5	20.3	587	73	8.5	14.9	14.2	24.8
2	1201	237	1.4	4.7	4.0	13.4	49	11	7.9	8.3	22.6	23.7	407	80	4.7	11.9	13.4	34.0
4	1449	248	1.4	4.7	4.0	13.4	66	14	6.5	7.7	18.6	22.0	462	79	5.2	10.4	14.9	29.7
5	468	164	2.3	5.6	3.8	9.3	6	2	5.3	8.9	8.8	14.8	135	52	7.7	18.9	12.8	31.5
7	645	178	2.3	5.8	3.8	9.7	20	5	14.1	17.2	23.5	28.7	201	59	6.4	15.3	10.7	25.5
6	434	128	1.4	4.3	4.0	12.3	20	6	6.7	11.6	19.1	33.1	164	47	4.8	12.3	13.7	35.1
8	500	151	1.8	6.2	5.1	17.7	28	9	5.4	10.7	15.4	30.6	141	47	5.6	14.8	16.0	42.3

Table 12 - (Continuation)

Restitution	d-points						e-points						g-points					
	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
1 x)	1644	236	9.4	15.6	15.7	26.0	406	70	4.6	16.2	7.7	27.0	2517	374	8.8	16.0	14.7	26.7
3	2208	280	8.4	14.8	14.0	24.7	546	92	4.8	15.6	8.0	26.0	3382	453	8.0	14.9	13.3	24.9
2	1444	286	5.1	12.3	14.6	35.1	310	76	3.5	12.0	10.0	34.3	2210	453	4.9	12.1	14.1	34.6
4	1700	292	5.2	9.8	14.9	28.0	436	94	3.8	9.9	10.9	28.3	2664	479	5.0	9.9	14.5	28.3
5	505	188	7.9	17.5	13.2	29.2	148	74	5.5	18.3	9.2	30.5	798	316	7.5	17.8	12.6	29.7
7	814	232	7.0	16.4	11.7	27.2	210	80	4.9	18.1	8.2	30.2	1245	376	6.8	16.5	11.4	27.5
6	573	170	5.8	13.3	16.6	38.0	132	52	4.8	11.3	13.7	32.3	889	275	5.5	12.8	15.8	36.7
8	522	184	5.7	13.5	16.3	38.6	160	68	3.2	9.6	9.1	27.4	851	308	5.3	13.1	15.2	37.4

N_M = Number of measurements

N_P = Number of points

x) see table 3

Table 13 - Systematic deviations (S 2)

Quadratic average of the differences between the mean values of the photogrammetrically determined co-ordinates and the terrestrial co-ordinates of comparison.

Compilation according to restitutions (chapter 4.2.4)

Restitution	a - points					b - points				
	N_p	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_p	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
1 x)	194	1.5	5.0	2.5	8.3	6	11.3	8.6	18.8	14.3
3	231	1.4	3.4	2.3	5.7	8	6.4	6.1	10.7	10.2
2	237	1.1	3.5	3.1	10.0	11	6.7	5.0	19.1	14.3
4	248	1.2	3.4	3.4	9.7	14	5.4	5.1	15.4	14.6
5	164	1.6	4.3	2.7	7.2	2	9.8	7.2	16.3	12.0
7	178	1.7	4.3	2.8	7.2	5	7.8	11.6	13.0	19.3
6	128	1.1	3.3	3.1	9.4	6	6.9	4.4	19.7	12.6
8	151	1.6	4.3	4.6	12.3	9	5.6	9.2	16.0	26.3

Restitution	c - points				
	N_p	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
1 x)	62	7.8	11.2	13.0	18.7
3	73	7.1	8.0	11.8	13.3
2	80	4.7	8.1	13.4	23.1
4	79	4.5	6.4	12.9	18.3
5	52	10.1	12.5	16.8	20.8
7	59	9.3	8.7	15.5	14.5
6	47	5.5	9.7	15.7	27.7
8	47	7.1	8.3	20.3	23.7

Table 13 - (Continuation)

Restitution	d - points					g - points				
	N_p	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_p	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
1 x)	236	5.8	11.4	9.7	19.0	304	6.4	11.3	10.7	18.9
3	280	5.3	10.5	8.8	17.5	361	5.7	10.0	9.5	16.6
2	286	4.5	9.2	12.9	26.3	377	4.6	8.9	13.2	25.4
4	292	3.6	7.1	10.3	20.3	385	3.9	6.9	11.1	19.7
5	188	8.2	15.1	13.7	25.2	242	8.7	14.5	14.4	24.2
7	232	7.5	13.6	12.5	22.7	296	7.9	12.7	13.2	21.3
6	170	4.7	8.4	13.4	24.0	223	4.9	8.6	14.1	24.6
8	184	5.0	9.7	14.3	27.7	239	5.5	9.4	15.7	26.9

N_p = Number of points (differences)

x) see table 3

M 3

Table 14 - Measuring accuracy (M3)
Compilation of the results according to different parameters (chapter 5.2.1)

Restitution	a - points					b - points					c - points					g - points				
	N_M	m_k (cm)	m_z (cm)	m_k (μm)	m_z (μm)	N_M	m_k (cm)	m_z (cm)	m_k (μm)	m_z (μm)	N_M	m_k (cm)	m_z (cm)	m_k (μm)	m_z (μm)	N_M	m_k (cm)	m_z (cm)	m_k (μm)	m_z (μm)
13	3118	2.0	5.4	3.3	9.1	65	3.7	7.2	6.1	12.1	913	3.0	6.8	5.1	11.3	978	3.1	6.8	5.2	11.4
24	2724	1.0	2.8	2.8	8.0	103	2.9	3.0	8.3	8.5	809	1.6	3.8	4.7	10.8	912	1.8	3.7	5.2	10.6
12	2629	-	-	2.9	8.7	69	-	-	7.4	8.9	773	-	-	5.1	11.7	842	-	-	5.3	11.5
34	3213	-	-	3.1	8.6	99	-	-	7.6	10.8	949	-	-	4.8	10.5	1048	-	-	5.1	10.5
1324	5842	-	-	3.0	8.6	168	-	-	7.5	10.0	1722	-	-	4.9	11.1	1890	-	-	5.2	11.0
57	1023	2.2	4.6	3.6	7.7	24	5.9	7.1	9.9	11.7	278	3.5	7.2	5.9	12.0	302	3.7	7.2	6.3	12.0
68	914	1.2	3.2	3.4	9.3	45	2.4	3.9	6.9	11.2	282	2.2	5.4	6.2	15.5	327	2.2	5.2	6.3	15.0
56	841	-	-	3.6	8.6	20	-	-	6.9	11.7	258	-	-	6.6	16.4	278	-	-	6.6	16.1
78	1096	-	-	3.5	8.4	49	-	-	8.5	11.3	302	-	-	5.6	11.3	351	-	-	6.1	11.3
5768	1937	-	-	3.5	8.5	69	-	-	8.1	11.4	560	-	-	6.1	13.9	629	-	-	6.3	13.6
1357	4141	2.1	5.2	3.4	8.8	89	4.4	7.2	7.3	12.0	1191	3.1	6.9	5.3	11.5	1280	3.2	6.9	5.5	11.5
2468	3638	1.1	2.9	3.0	8.3	148	2.8	3.3	7.9	9.4	1091	1.8	4.3	5.1	12.2	1239	1.9	4.2	5.5	11.9
1256	3470	-	-	3.1	8.7	89	-	-	7.3	9.6	1031	-	-	5.5	13.0	1120	-	-	5.7	12.8
3478	4309	-	-	3.2	8.5	148	-	-	7.9	11.0	1251	-	-	5.0	10.7	1399	-	-	5.4	10.7

N_M = Number of double measurements (differences)

A 3

Table 15 - Absolute accuracy (A 3)
Compilation of the results according to different parameters (chapter 5.2.2)

Restitution	a - points					b - points					c - points				
	N_M	m_k (cm)	m_z (cm)	m_k (μm)	m_z (μm)	N_M	m_k (cm)	m_z (cm)	m_k (μm)	m_z (μm)	N_M	m_k (cm)	m_z (cm)	m_k (μm)	m_z (μm)
13	3151	3.0	7.9	5.0	13.1	74	12.9	12.6	21.5	21.0	1021	11.0	17.4	18.3	29.0
24	2650	2.1	6.1	6.0	17.4	115	8.5	8.7	24.1	24.8	869	6.2	11.8	17.7	33.8
12	2602	-	-	5.5	15.8	82	-	-	26.3	23.8	841	-	-	17.9	34.7
34	3199	-	-	5.5	14.8	107	-	-	20.3	23.1	1049	-	-	18.1	28.3
1324	5801	-	-	5.5	15.2	189	-	-	23.1	23.4	1890	-	-	18.0	31.3
57	1113	3.0	7.6	5.0	12.7	26	13.2	17.6	22.1	29.4	336	11.7	15.8	19.4	26.3
68	934	2.3	6.6	6.6	19.0	48	7.7	11.8	22.0	33.8	305	7.4	13.4	21.2	38.2
56	902	-	-	5.5	13.7	26	-	-	21.6	27.7	299	-	-	19.8	34.5
78	1145	-	-	6.0	17.4	48	-	-	22.2	34.6	342	-	-	20.7	30.6
5768	2047	-	-	5.8	15.9	74	-	-	22.0	32.3	641	-	-	20.3	32.5
1357	4264	3.0	7.8	5.0	13.0	100	13.0	14.1	21.7	23.5	1357	11.2	17.0	18.6	28.4
2468	3584	2.2	6.2	6.2	17.8	163	8.3	9.7	23.5	27.8	1174	6.5	12.2	18.7	35.0
1256	3504	-	-	5.5	15.3	108	-	-	25.2	24.8	1140	-	-	18.4	34.6
3478	4344	-	-	5.6	15.5	155	-	-	20.9	27.2	1391	-	-	18.8	28.9

A 3

Table 15 - (Continuation)

Resti-tution	d - points N_M	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	g - points N_M	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
13	3852	9.8	16.9	16.4	28.2	4947	10.1	16.9	16.9	28.3
24	3144	6.1	11.7	17.4	33.5	4128	6.2	11.6	17.7	33.4
12	3088	-	-	17.6	33.4	4011	-	-	17.9	33.5
34	3908	-	-	16.2	28.3	5064	-	-	16.7	28.2
1324	6996	-	-	16.8	30.7	9075	-	-	17.2	30.7
57	1319	10.0	18.6	16.7	31.1	1681	10.4	18.1	17.4	30.2
68	1095	6.7	13.0	19.0	37.1	1448	6.9	13.0	19.6	37.2
56	1078	-	-	18.3	35.0	1403	-	-	18.7	34.8
78	1336	-	-	17.4	33.0	1726	-	-	18.2	32.6
5768	2414	-	-	17.8	33.9	3129	-	-	18.4	33.6
1357	5171	9.9	17.3	16.5	29.0	6628	10.2	17.2	17.0	28.8
2468	4239	6.4	12.3	18.1	35.1	5576	6.5	12.2	18.4	34.9
1256	4166	-	-	17.8	33.8	5414	-	-	18.1	33.8
3478	5244	-	-	16.5	29.6	6790	-	-	17.1	19.4

N_M = Number of measurements

A 4

Table 16 - Absolute accuracy (A4)
Compilation of the results according to different Restitution Centres (mean values obtained from four measurements), as well as standard deviations of the single measurements, in "µm in the image" (chapter 5.2.2)

Restitution	Resti-tution Centre	a-points m'_k	a-points m'_z	d-points m'_k	d-points m'_z	a-points m'_{mk}	a-points m_{mz}	d-points m_{mk}	d-points m_{mz}
1324 (1st operator)	0	4.7	16.8	14.1	30.8	1.3	5.5	2.8	7.9
	1	4.7	13.6	15.2	29.0	0.8	2.0	1.6	1.5
	2	6.8	17.5	15.2	28.0	0.2	2.1	2.2	5.2
	3	4.9	13.9	17.9	35.1	1.4	3.7	1.4	9.3
	4	5.8	12.9	15.9	27.5	0.7	2.2	1.2	5.4
	5	4.4	14.6	11.5	28.9	0.8	3.7	1.0	13.5
	6	5.6	16.2	25.7	32.8	0.4	4.7	1.2	4.4
	7	4.6	13.6	14.7	33.2	0.2	3.3	2.6	3.1
	8	6.0	15.3	15.9	35.0	0.7	3.3	2.2	1.1
	9	5.4	16.8	19.1	41.0	1.2	3.6	3.8	6.7
	0 to 9	5.3	15.1	16.5	32.1	0.9	3.6	2.2	6.5
	1)					0.5	1.8	1.1	3.2
	2)					0.7	1.5	3.6	4.0
5768 (2nd operator)	0	5.5	17.5	14.5	34.6	2.3	5.8	4.4	11.4
	4	5.6	12.0	16.2	22.3	0.9	2.5	2.5	2.6
	5	5.6	20.1	20.4	52.2	2.5	11.3	5.7	35.8
	6	6.3	11.4	23.9	29.3	0.5	1.9	2.2	6.7
	7	4.4	13.9	15.3	26.2	1.0	3.1	2.1	3.2
	8	7.2	15.4	17.7	48.0	0.5	3.3	1.7	5.7
	9	5.8	17.9	16.2	38.4	1.8	3.3	2.3	10.1
	0 to 9	5.8	15.5	17.7	35.9	1.5	5.3	3.3	15.3
	1)					0.8	2.7	1.6	7.6
	2)					0.8	3.0	3.1	10.3
1324-5768 (1st-2nd oper.)	3)					0.6	2.0	2.6	7.7

1) Mean deviations of the mean values m'_k and m'_z resulting from deviations of the four single values m_k and m_z respectively as compared to the mean value.

2) Mean deviations of the mean values m'_k and m'_z resulting from deviations of the ten and seven values respectively as compared to the total mean $\bar{m}_k$ and $\bar{m}_z$.

3) Mean deviations of the mean values m'_k and m'_z resulting from the seven differences of the values for the two operators of a Restitution Centre.

R 3

Table 17 - Relative accuracy (R3)
Compilation of the results according to different parameters (chapter 5.2.3)

Restitution	a - points						b - points						c - points					
	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
13	2151	425	2.1	5.9	3.5	9.8	74	14	11.3	11.9	18.8	19.8	1021	135	8.8	16.1	14.6	26.9
24	2650	485	1.4	4.7	4.0	13.4	115	25	7.1	8.0	20.4	22.7	869	159	5.0	11.1	14.2	27.2
12	2602	431	-	-	3.6	11.7	82	17	-	-	21.7	21.9	841	142	-	-	14.4	31.7
34	3199	479	-	-	3.8	11.4	107	22	-	-	18.2	21.4	1049	152	-	-	14.5	27.0
1324	5801	910	-	-	3.7	11.5	189	39	-	-	19.8	21.6	1890	294	-	-	14.5	29.1
57	1113	342	2.3	5.7	3.8	9.5	26	7	12.8	15.8	21.3	26.4	336	111	6.9	16.7	11.5	27.9
68	934	279	1.6	5.4	4.6	15.4	48	15	6.0	11.1	17.1	31.7	305	94	5.2	13.5	14.8	38.5
56	902	292	-	-	3.9	10.9	26	8	-	-	17.3	30.0	299	99	-	-	13.3	33.6
78	1145	329	-	-	4.4	13.7	48	14	-	-	19.4	29.8	342	106	-	-	13.1	33.2
5768	2047	621	-	-	4.2	12.6	74	22	-	-	18.7	29.9	641	205	-	-	13.2	33.4
1357	4246	767	2.1	5.9	3.6	9.7	100	21	11.7	12.9	19.4	21.6	1357	246	8.4	16.2	14.0	27.1
2468	3584	764	1.4	4.9	4.1	13.9	163	40	6.8	8.9	19.6	25.4	1174	253	5.0	11.7	14.3	30.2
1256	3504	723	-	-	3.7	11.5	108	25	-	-	20.8	23.9	1140	241	-	-	14.2	32.1
3478	4344	808	-	-	3.9	12.0	155	36	-	-	18.6	24.1	1391	258	-	-	14.2	28.4

R 3

Table 17 - (Continuation)

Restitution	d - points						e - points						g - points					
	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_M	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
13	3852	516	8.8	15.1	14.7	25.3	952	162	4.7	15.9	7.9	26.4	5899	827	8.3	15.4	13.9	25.7
24	3144	578	5.2	11.0	14.8	31.4	746	170	3.7	10.8	10.5	30.9	4874	932	5.0	10.9	14.3	30.4
12	3088	522	-	-	15.2	30.4	716	146	-	-	8.7	30.2	4727	827	-	-	14.4	30.5
34	3908	572	-	-	14.4	26.1	982	186	-	-	9.4	27.0	6046	932	-	-	13.8	26.3
1324	6996	1094	-	-	14.8	28.1	1698	332	-	-	9.1	28.4	10773	1759	-	-	14.1	28.2
57	1319	420	7.3	16.8	12.3	28.0	358	154	5.1	18.2	8.6	30.3	2039	692	7.1	17.0	11.9	28.3
68	1095	354	5.8	13.4	16.5	38.3	292	120	4.0	10.4	11.5	29.8	1740	583	5.5	13.0	15.6	37.0
56	1078	358	-	-	15.2	34.4	280	126	-	-	11.8	31.4	1683	591	-	-	14.5	33.8
78	1336	416	-	-	13.6	31.9	370	148	-	-	8.6	29.1	2096	684	-	-	13.0	31.6
5768	2414	774	-	-	14.3	33.0	650	274	-	-	10.0	30.1	3779	1275	-	-	13.6	32.6
1357	5171	936	8.5	15.5	14.2	25.9	1310	316	4.8	16.4	8.0	27.2	7938	1519	8.1	15.7	13.5	26.3
2468	4239	932	5.3	11.6	15.2	33.1	1038	290	3.8	10.7	10.7	30.6	6614	1515	5.2	11.4	14.6	32.1
1256	4166	880	-	-	15.2	31.3	996	272	-	-	9.4	30.5	6410	1418	-	-	14.4	31.2
3478	5244	988	-	-	14.2	27.4	1352	334	-	-	9.2	27.5	8142	1616	-	-	13.6	27.5

N_M = Number of measurement

N_P = Number of points

Table 18 - Systematic deviations (S3)
Compilation of the results according to different parameters (chapter 5.2.4)

Restitution	a - points					b - points					c - points				
	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
13	425	1.4	4.2	2.4	7.0	14	8.8	7.3	14.7	12.1	135	7.4	9.6	12.4	16.0
24	485	1.2	3.4	3.2	9.8	25	6.0	5.1	17.1	14.5	159	4.6	7.3	13.2	20.8
12	431	-	-	2.8	9.3	17	-	-	19.0	14.3	142	-	-	13.2	21.3
34	479	-	-	2.9	8.0	22	-	-	13.9	13.2	152	-	-	12.4	16.1
1324	910	-	-	2.9	8.6	39	-	-	16.3	13.7	294	-	-	12.8	18.8
57	342	1.7	4.3	2.8	7.2	7	8.4	10.5	14.0	17.5	111	9.7	10.7	16.1	17.7
68	279	1.4	3.9	4.0	11.1	15	6.2	7.7	17.6	21.9	94	6.4	9.0	18.1	25.8
56	292	-	-	2.9	8.2	8	-	-	18.9	12.4	99	-	-	16.3	24.3
78	329	-	-	3.7	9.9	14	-	-	15.0	24.0	106	-	-	17.8	19.1
5768	621	-	-	3.4	9.1	22	-	-	16.5	20.6	205	-	-	17.1	21.8
1357	767	1.5	4.2	2.6	7.1	21	8.7	8.5	14.5	14.1	246	8.5	10.1	14.2	16.8
2468	764	1.3	3.6	3.5	10.3	40	6.1	6.2	17.3	17.6	253	5.3	8.0	15.2	22.8
1256	723	-	-	2.8	8.9	25	-	-	19.0	13.7	241	-	-	14.6	22.6
3478	808	-	-	3.2	8.8	36	-	-	14.3	18.2	258	-	-	14.9	17.4

Table 18 -(Continuation)

Restitution	d - points					g - points				
	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)	N_P	m_k (cm)	m_z (cm)	m_k (µm)	m_z (µm)
13	516	5.5	10.9	9.2	18.2	665	6.0	10.6	10.1	17.7
24	518	4.1	8.2	11.7	23.5	762	4.3	7.9	12.2	22.7
12	522	-	-	11.6	23.3	681	-	-	12.2	22.7
34	572	-	-	9.6	19.0	746	-	-	10.4	18.3
1324	1094	-	-	10.6	21.1	1427	-	-	11.2	20.5
57	420	7.8	14.3	13.0	23.9	538	8.2	13.6	13.7	22.7
68	354	4.9	9.1	13.9	26.0	463	5.3	9.0	15.0	25.8
56	358	-	-	13.6	24.6	465	-	-	14.3	24.4
78	416	-	-	13.3	25.0	536	-	-	14.3	23.9
5768	774	-	-	13.4	24.8	1001	-	-	14.3	24.2
1357	936	6.6	12.5	11.1	21.0	1203	7.1	12.0	11.9	20.1
2468	932	4.4	8.6	12.6	24.5	1225	4.7	8.4	13.4	24.0
1256	880	-	-	12.5	23.8	1146	-	-	13.1	23.4
3478	988	-	-	11.3	21.7	1282	-	-	12.2	20.8

N_P = Number of points (differences)

Table 19 - Comparison of the absolute and relative accuracy. Proof of the significance of the systematic deviations with a significance level of 5%. (F-test accord. to Fisher) (chapter 5.2.4)

Point type	Restitution	N_M	N_P	N_{St}	Degrees of freedom N_{Axy}	N_{Az}	N_R	K_{xy}	K_z	F_{Tab} xy	z
a	1	1401	194	56	794	997	1207	0.69	0.83	1.12	1.12
	3	1750	231	65	1011	1258	1519	0.67	0.83	1.11	1.10
	2	1201	237	66	699	867	964	0.73	0.90	1.12	1.12
	4	1449	248	68	853	1052	1201	0.71	0.88	1.12	1.12
	5	468	164	47	267	334	304	0.88	1.10	1.22	1.21
	7	645	178	52	362	457	467	0.78	0.98	1.18	1.17
	6	434	128	37	246	309	306	0.80	1.01	1.22	1.21
	8	500	151	39	306	371	349	0.88	1.06	1.21	1.20
b	1	33	6		33		27	1.22		1.87	
	3	41	8		41		33	1.24		1.76	
	2	49	11		49		38	1.29		1.68	
	4	66	14		66		52	1.27		1.56	
	5	6	2		6		4	1.50		6.16	
	7	20	5		20		15	1.33		2.33	
	6	20	6		20		14	1.43		2.39	
	8	28	9		28		19	1.47		2.09	
c	1	434	62		434		372	1.17		1.18	
	3	587	73		587		514	1.14		1.16	
	2	407	80		407		327	1.24		1.20	
	4	462	79		462		383	1.21		1.19	
	5	135	52		135		83	1.63		1.42	
	7	201	59		201		142	1.42		1.32	
	6	164	47		164		117	1.40		1.34	
	8	141	47		141		94	1.50		1.39	
d	1	1644	236		1644		1408	1.17		1.09	
	3	2208	280		2208		1928	1.15		1.08	
	2	1444	286		1444		1158	1.25		1.09	
	4	1700	292		1700		1408	1.21		1.09	
	5	505	188		505		317	1.59		1.18	
	7	814	232		814		582	1.40		1.14	
	6	573	170		573		403	1.42		1.17	
	8	522	184		522		338	1.54		1.17	

Table 19 - (Continuation)

Point type	Restitution	x m_A	x m_R	y m_A	y m_R	z m_A	z m_R
a	1	3.0	2.0	3.0	2.0	8.5	6.1
	3	3.0	2.1	3.1	2.2	7.3	5.7
	2	1.9	1.3	2.2	1.4	6.1	4.7
	4	1.9	1.2	2.3	1.5	6.1	4.7
	5	2.8	2.1	3.2	2.4	6.9	5.6
	7	2.7	1.9	3.5	2.6	8.1	5.8
	6	1.8	1.3	2.2	1.5	5.5	4.3
	8	2.4	1.7	2.8	1.8	7.5	6.2
b	1	14.7	12.2	14.9	12.1	13.0	11.5
	3	12.6	12.3	9.5	8.4	12.3	12.2
	2	9.4	8.7	9.8	7.1	8.8	8.3
	4	7.5	7.0	7.4	6.0	8.6	7.7
	5	10.9	4.0	7.6	6.4	11.0	8.9
	7	17.4	14.7	13.6	13.4	19.2	17.2
	6	7.2	6.0	8.8	7.2	10.5	11.6
	8	6.4	5.5	8.3	5.4	12.7	10.7
c	1	10.7	8.8	11.7	9.3	19.7	17.7
	3	10.4	8.2	11.1	8.7	15.5	14.9
	2	5.9	4.8	6.1	4.7	12.8	11.9
	4	6.5	5.2	6.4	5.2	10.9	10.4
	5	12.2	8.4	12.1	7.0	17.2	18.9
	7	10.3	6.0	12.2	6.7	14.7	15.3
	6	6.6	5.0	6.9	4.6	13.5	12.3
	8	7.8	5.3	8.4	5.9	13.2	14.8
d	1			10.3	9.4	17.5	15.6
	3			9.4	8.4	16.5	14.8
	2			6.3	5.1	13.2	12.3
	4			5.9	5.2	10.3	9.8
	5			10.4	7.9	18.7	17.5
	7			9.8	7.0	18.6	16.4
	6			6.7	5.8	13.3	13.3
	8			6.6	5.7	12.6	13.5

Table 19 - (Continuation)

Point type	Restitution	F_x	F_y	F_z	F_x ±	F_y ±	F_z ±
a	1	1.46	1.56	1.59	-	-	-
	3	1.35	1.31	1.34	-	-	-
	2	1.56	1.80	1.51	-	-	-
	4	1.64	1.67	1.48	-	-	-
	5	1.55	1.55	1.66	-	-	-
	7	1.58	1.41	1.91	-	-	-
	6	1.54	1.72	1.66	-	-	-
	8	1.75	2.13	1.55	-	-	-
b	1	1.76	1.85	1.56	+	+	+
	3	1.30	1.59	1.26	+	+	+
	2	1.51	2.46	1.44	+	-	+
	4	1.46	1.93	1.59	+	-	-
	5	11.15	2.12	2.30	-	+	+
	7	1.86	1.37	1.66	+	+	+
	6	2.06	2.10	1.17	+	+	+
	8	1.98	3.47	2.07	+	-	+
c	1	1.73	1.85	1.45	-	-	-
	3	1.84	1.86	1.23	-	-	-
	2	1.87	2.08	1.44	-	-	-
	4	1.89	1.83	1.33	-	-	-
	5	3.44	4.87	1.35	-	-	+
	7	4.19	4.71	1.31	-	-	+
	6	2.44	3.15	1.68	-	-	-
	8	3.25	3.05	1.20	-	-	+
d	1		1.40	1.47		-	-
	3		1.44	1.43		-	-
	2		1.91	1.44		-	-
	4		1.56	1.33		-	-
	5		2.75	1.81		-	-
	7		2.74	1.81		-	-
	6		1.89	1.42		-	-
	8		2.06	1.34		-	-

Table 20 - Compilation of some standard errors of terrestrial and photogrammetric measurements in "cm in the terrain" (chapter 6.1)

Restitution	Type of error	m_k					m_z					from table
		a	b	c	d	g	a	b	c	d	g	
	T	1.3	2.9	1.7	2.1	2.1	1.3	4.6	1.9	2.7	2.7	6
13 (1:6 000)	A	3.0	12.9	11.0	9.8	10.1	7.9	12.6	17.4	16.9	16.9	15
	R	2.1	11.3	8.8	8.8	8.8	5.9	11.9	16.1	15.1	15.3	17x)
	S	1.4	8.8	7.4	5.5	6.0	4.2	7.3	9.6	10.9	10.6	18
24 (1:3 500)	A	2.1	8.5	6.2	6.1	6.2	6.1	8.7	11.8	11.7	11.6	15
	R	1.4	7.1	5.0	5.2	5.2	4.7	8.0	11.1	11.0	11.0	17x)
	S	1.2	6.0	4.6	4.1	4.3	3.4	5.1	7.3	8.2	7.9	18
57 (1:6 000)	A	3.0	13.2	11.7	10.0	10.4	7.7	17.6	15.8	18.6	18.1	15
	R	2.3	12.8	6.9	7.3	7.3	5.7	15.8	16.7	16.8	16.8	17x)
	S	1.7	8.4	9.7	7.8	8.2	4.3	10.5	10.7	14.3	13.6	18
68 (1:3 500)	A	2.3	7.7	7.4	6.7	6.9	6.6	11.8	13.4	13.0	13.0	15
	R	1.6	6.0	5.2	5.8	5.7	5.4	11.1	13.5	13.4	13.4	17x)
	S	1.4	6.2	6.4	4.9	5.3	3.9	7.7	9.0	9.1	9.0	18

a, b, c, d = point types
g = non-signalised building points (b-, c- and d-points)
T = standard errors of the terrestrial measurements
x) The relative accuracy of the g-points differs slightly from the values indicated in table 17. In that table the e-points are included.

Table 21 - Compilation of the ratios V_A of some standard errors in "cm in the terrain" of the two survey procedures (chapter 6.1)

V_A	1:m_b	V_A of m_k					V_A of m_z				
		a	b	c	d	g	a	b	c	d	g
A:T	1:6 000	2.31	4.45	6.48	4.67	4.81	6.08	2.74	9.15	6.26	6.26
	1:3 500	1.62	2.94	3.65	2.91	2.95	4.69	1.89	6.20	4.34	4.30
	1:1 000	0.42	0.80	1.06	0.80	0.82	1.17	0.51	1.64	1.14	1.14
R:T	1:6 000	1.62	3.90	5.17	4.19	4.19	4.54	2.58	8.46	5.60	5.67
	1:3 500	1.08	2.45	2.94	2.48	2.48	3.62	1.74	5.84	4.08	4.08
	1:1 000	0.28	0.68	0.85	0.70	0.70	0.88	0.47	1.53	1.04	1.05
S:T	1:6 000	1.08	3.04	4.35	2.62	2.86	3.24	1.59	5.05	4.04	3.92
	1:3 500	0.92	2.07	2.71	1.95	2.05	2.62	1.11	3.84	3.04	2.92
	1:1 000	0.22	0.56	0.75	0.50	0.53	0.66	0.30	0.99	0.78	0.76

Table 22 - Compilation of the ratios V_p of the standard errors in "µm in the image" of the different point types (chapter 6.2)

Restitution	Type of error	V_p of m_k					V_p of m_z					from table
		$\frac{a}{c}$	$\frac{b}{c}$	$\frac{d}{c}$	$\frac{e}{c}$	$\frac{g}{c}$	$\frac{a}{c}$	$\frac{b}{c}$	$\frac{d}{c}$	$\frac{e}{c}$	$\frac{g}{c}$	
1234	M	0.61	1.53	-	-	1.06	0.77	0.90	-	-	0.99	14
	A	0.31	1.28	0.93	-	0.96	0.49	0.74	0.98	-	0.98	15
	R	0.26	1.37	1.02	0.63	0.97	0.40	0.74	0.97	0.98	0.97	17
	S	0.23	1.27	0.83	-	0.88	0.46	0.73	1.12	-	1.09	18
5678	M	0.57	1.33	-	-	1.03	0.61	0.82	-	-	0.98	14
	A	0.29	1.08	0.88	-	0.91	0.49	1.00	1.04	-	1.04	15
	R	0.32	1.42	1.08	0.76	1.03	0.38	0.90	0.99	0.90	0.98	17
	S	0.20	0.97	0.78	-	0.84	0.42	0.95	1.14	-	1.11	18

Table 23 - Compilation of the ratios V_M of the standard errors in "µm in the image" for both photo scales (chapter 6.3)

V_M	Type of errors	V_M of m_k						V_M of m_z						from table
		a	b	c	d	e	g	a	b	c	d	e	g	
24:13 (1:3 500 / 1:6 000)	M	0.85	1.36	0.92	-	-	1.00	0.88	0.70	0.96	-	-	0.93	14
	A	1.20	1.12	0.97	1.06	-	1.06	1.33	1.18	1.17	1.19	-	1.17	15
	R	1.14	1.09	0.97	1.01	1.33	1.03	1.37	1.15	1.01	1.24	1.17	1.18	17
	S	1.33	1.16	1.06	1.27	-	1.21	1.40	1.20	1.30	1.29	-	1.28	18
68:57 (1:3 500 / 1:6 000)	M	0.94	0.70	1.05	-	-	1.00	1.21	0.96	1.29	-	-	1.25	14
	A	1.32	1.00	1.09	1.14	-	1.13	1.50	1.15	1.45	1.19	-	1.23	15
	R	1.21	0.80	1.29	1.34	1.34	1.31	1.62	1.20	1.38	1.37	0.98	1.31	17
	S	1.43	1.26	1.12	1.07	-	1.09	1.54	1.25	1.46	1.09	-	1.14	18

Table 24 - Compilation of the ratios V_B of the standard errors in "µm in the image" for the two operator groups (chapter 6.4)

V_B	Type of error	V_B of m_k						V_B of m_z						from table
		a	b	c	d	e	g	a	b	c	d	e	g	
5678 / 1234	M	1.17	1.08	1.22	-	-	1.21	0.99	1.14	1.25	-	-	1.24	14
(2^{nd} oper. / 1^{st} oper.)	A	1.05	0.95	1.13	1.06	-	1.07	1.05	1.38	1.04	1.10	-	1.09	15
	R	1.14	0.94	0.91	0.97	1.10	0.96	1.10	1.38	1.15	1.17	1.06	1.16	17
	S	1.17	1.01	1.34	1.26	-	1.28	1.06	1.50	1.16	1.18	-	1.18	18

Table 25 - Comparison of the mean values $\Delta\bar{q}$ in "cm in the terrain" of the two measurements of a Restitution Centre (t-test accord. to Student) (chapter 6.4)

Restitution	Restitution Centre	N_P	c-points									N_P	d-points					
			$\Delta\bar{x}1$	$\Delta\bar{x}2$	t	$\Delta\bar{y}1$	$\Delta\bar{y}2$	t	$\Delta\bar{z}1$	$\Delta\bar{z}2$	t		$\Delta\bar{y}1$	$\Delta\bar{y}2$	t	$\Delta\bar{z}1$	$\Delta\bar{z}2$	t
1-5	0	30	-3.8	-3.0	+	+4.6	+1.1	+	+0.8	+3.0	+	103	-1.1	0.0	+	-5.4	-6.4	+
	4	32	-4.1	-2.5	+	-0.5	-2.0	+	-7.0	-5.1	+	107	+0.3	-1.1	+	-7.4	-5.8	+
	5	17	+0.9	-2.1	+	-0.5	+1.1	+	+6.3	+5.4	+	75	+2.7	-0.8	-	-4.2	-5.2	+
	6	18	-4.5	-12.7	+	+7.7	-5.7	-	-5.8	-7.4	+	62	-7.2	-6.7	+	-10.5	-14.2	+
	7	19	-7.3	-4.9	+	-0.1	+0.7	+	+9.9	+4.8	+	74	-5.9	-4.7	+	+1.4	+3.2	+
	8	18	+4.5	-2.2	-	-3.2	+6.7	-	-5.6	+9.1	+	73	+1.7	-1.4	+	-13.8	-17.6	+
	9	-	-	-		-	-		-	-		-	-	-		-	-	
3-7	0	32	-4.9	-2.3	+	+3.9	+4.5	+	+1.8	+5.3	+	112	-0.5	-0.2	+	-2.9	+0.6	-
	4	33	-4.7	-2.8	+	+6.1	+0.7	-	-6.6	-7.2	+	115	+3.4	-3.1	-	-6.2	-8.4	+
	5	27	-0.6	-3.7	+	+1.3	+9.2	+	-1.4	+3.2	+	115	+2.3	-2.7	-	+0.5	-0.7	+
	6	27	-7.6	-7.6	+	+5.5	+4.4	+	-8.4	-2.3	+	113	-8.5	-6.6	+	-6.5	+0.1	-
	7	27	-3.8	-1.3	+	+3.1	+0.7	+	+9.2	+5.2	+	117	-1.3	-2.1	+	+0.7	+2.7	+
	8	25	+0.9	-2.5	+	+4.7	+4.6	+	-15.1	-22.0	+	112	+4.3	+0.4	-	-17.3	-21.3	-
	9	28	-3.5	-2.4	+	+2.2	+2.7	+	-2.5	+1.5	+	113	-1.8	-3.3	+	+0.9	+3.6	+
2-6	0	22	-3.0	-2.8	+	-0.4	-0.7	+	+5.2	+7.0	+	85	+0.6	+0.4	+	+1.8	+4.2	+
	4	22	-2.0	-4.0	+	+0.9	-1.6	-	-5.8	-2.2	-	87	+1.3	-1.2	-	-4.3	-0.9	-
	5	24	+1.4	-1.0	-	+2.1	+0.9	+	-0.9	+12.8	-	81	+2.6	+2.6	+	-4.5	+14.4	-
	6	23	+0.1	-2.3	+	+0.7	+0.5	+	-3.4	+2.6	+	75	-5.0	-6.1	+	-7.0	+0.5	-
	7	24	+0.7	-1.0	+	-0.7	0.0	+	+9.9	+3.1	-	79	-0.4	-1.2	+	+3.4	+3.3	+
	8	24	+0.5	-1.5	+	-0.6	+0.5	+	-9.1	-3.8	+	79	+2.9	+1.9	+	-11.2	-5.3	-
	9	23	+0.7	+1.7	+	-2.5	-1.7	+	+8.0	+10.9	+	81	-0.6	-1.8	+	+10.9	+14.5	+
4-8	0	22	-4.7	-4.8	+	+2.2	+2.4	+	-9.2	-11.0	+	84	-0.4	-1.0	+	+9.5	-13.6	-
	4	23	-4.8	-6.3	+	+3.6	+2.5	+	-7.7	-3.4	-	85	-0.4	-3.4	-	-5.9	-2.9	-
	5	10	+0.7	+2.1	+	+3.0	+1.8	+	-2.8	+36.9	-	25	+3.3	+0.5	+	-1.2	+33.8	-
	6	22	+1.0	-3.5	-	-0.3	+5.8	-	-0.6	+3.9	-	82	-6.0	-5.0	+	-1.5	+1.8	-
	7	24	-0.6	-3.7	-	+5.2	+3.2	+	+6.6	+3.5	+	95	+0.1	-1.5	-	+1.2	+2.5	+
	8	24	+0.4	-4.0	-	+1.2	+4.9	+	-6.8	-8.7	+	95	+2.6	-0.5	-	-7.0	-8.7	+
	9	15	-2.2	+0.2	+	+1.0	+0.9	+	-5.0	0.0	+	53	-0.9	-0.7	+	-4.8	+2.1	-

+ = Agreement - = Disagreement Significance level 5%

Table 26 - Comparison of the standard errors in "cm in the terrain" of the measurements of a Restitution Centre (F-test accord. to Fisher) (chapter 6.4)

Restitution	Restitution Centre	a-points									
		N_P	m_{x1}	m_{x2}	F	m_{y1}	m_{y2}	F	m_{z1}	m_{z2}	F
1-5	0	87	1.5	1.7	+	1.6	1.6	+	7.7	8.7	+
	4	87	2.8	2.3	+	2.7	2.6	+	5.3	4.8	+
	5	74	1.7	1.8	+	2.0	2.1	+	6.5	4.9	-
	6	66	2.2	2.8	-	2.7	3.0	+	5.2	4.3	+
	7	75	1.6	1.6	+	2.1	1.8	+	4.7	5.5	+
	8	74	2.0	2.8	-	2.6	3.6	-	6.0	6.0	+
	9	-	-	-		-	-		-	-	
3-7	0	83	1.8	2.1	+	1.8	2.1	+	6.7	6.5	+
	4	84	3.0	2.1	-	3.1	2.8	+	6.0	5.3	+
	5	94	1.6	1.5	+	1.7	2.1	-	6.7	6.3	+
	6	89	2.7	3.1	+	2.1	3.3	-	6.7	6.4	+
	7	97	1.6	1.5	+	2.0	1.7	+	5.6	6.3	+
	8	96	2.4	2.2	+	3.1	3.9	-	6.1	6.9	+
	9	97	1.8	1.9	+	1.9	1.9	+	7.2	7.7	+
2-6	0	67	1.2	1.1	+	1.3	1.2	+	4.4	4.2	+
	4	67	1.3	1.3	+	1.3	1.6	+	3.5	4.5	-
	5	59	1.2	0.9	-	1.6	1.0	-	5.6	5.0	+
	6	57	1.3	1.7	-	1.5	1.7	+	4.5	3.6	+
	7	60	1.1	1.3	+	1.1	1.4	-	4.2	4.7	+
	8	61	1.6	1.5	+	2.2	2.6	+	4.6	5.2	+
	9	61	2.1	2.1	+	1.6	2.0	+	6.3	6.4	+
4-8	0	68	2.0	2.2	+	2.2	2.6	+	8.0	7.8	+
	4	68	1.6	1.5	+	2.3	2.3	+	4.1	4.2	+
	5	76	1.3	2.6	-	1.4	2.4	-	4.7	10.3	-
	6	80	1.4	1.6	+	1.5	1.9	-	5.4	3.6	-
	7	83	1.1	1.4	-	1.3	1.6	-	4.8	5.3	+
	8	83	1.5	1.6	+	2.1	2.4	+	6.0	5.9	+
	9	42	1.6	1.8	+	2.0	2.0	+	5.5	6.1	+

Table 26 - (Continuation)

Restitution	Restitution Centre	c-points									
		N_P	m_{x1}	m_{x2}	F	m_{y1}	m_{y2}	F	m_{z1}	m_{z2}	F
1-5	0	30	7.0	6.4	+	7.6	9.3	+	19.4	20.2	+
	4	32	7.5	8.7	+	11.5	8.2	-	9.5	8.3	+
	5	17	4.9	10.5	-	6.7	17.0	-	13.3	16.7	+
	6	18	10.6	19.8	-	16.4	14.8	+	16.5	14.3	+
	7	19	13.6	9.6	+	13.0	10.4	+	20.3	11.9	-
	8	18	7.6	11.3	+	7.0	13.4	-	13.8	33.5	-
	9	-	-	-		-	-		-	-	
3-7	0	32	6.5	5.4	+	7.3	6.5	+	13.1	13.2	+
	4	33	7.1	7.9	+	13.8	10.5	+	9.9	9.7	+
	5	27	5.0	13.7	-	5.8	16.4	-	10.5	14.6	+
	6	27	12.2	12.1	+	10.5	13.3	+	14.4	13.4	+
	7	27	11.8	7.7	-	11.6	10.0	+	13.5	7.2	-
	8	25	10.2	9.3	+	8.5	12.2	-	12.0	17.9	-
	9	28	8.9	10.1	+	7.3	10.3	-	21.8	13.9	-
2-6	0	22	5.8	4.7	+	6.5	5.3	+	11.0	12.1	+
	4	22	4.4	4.8	+	3.9	4.9	+	5.4	7.3	+
	5	24	4.4	4.5	+	4.4	8.1	-	11.4	15.9	+
	6	23	5.7	9.6	-	6.2	8.7	+	13.2	10.8	+
	7	24	6.8	5.0	+	7.3	6.7	+	12.7	7.3	-
	8	24	4.4	7.0	-	4.7	6.7	+	8.5	17.7	-
	9	23	4.8	7.0	-	4.9	7.9	-	13.7	13.7	+
4-6	0	22	6.6	6.5	+	6.6	7.6	+	8.5	11.1	+
	4	23	4.6	6.6	+	10.4	8.3	+	7.7	5.9	+
	5	10	3.7	5.8	+	4.3	12.0	-	9.8	10.3	+
	6	22	5.8	10.5	-	6.2	7.8	+	6.3	7.5	+
	7	24	5.5	4.2	+	5.6	6.8	+	11.8	9.3	+
	8	24	5.1	4.9	+	5.0	5.5	+	11.0	10.2	+
	9	15	6.1	5.0	+	3.0	4.7	+	6.1	6.6	+

Table 26 - (Continuation)

Restitution	Restitution Centre	d-points						
		N_P	m_{y1}	m_{y2}	F	m_{z1}	m_{z2}	F
1-5	0	103	7.4	8.6	+	13.0	18.9	-
	4	107	9.3	9.0	+	12.5	10.0	-
	5	75	6.9	9.6	-	15.9	22.2	-
	6	62	10.6	13.8	-	17.8	19.0	+
	7	74	6.5	9.6	-	18.1	13.0	-
	8	73	9.1	9.7	+	16.3	27.0	-
	9	-	-	-		-	-	
3-7	0	112	8.3	5.1	-	12.3	12.3	+
	4	115	7.8	7.6	+	9.2	11.6	-
	5	115	6.7	11.5	-	12.2	18.3	-
	6	113	10.7	10.7	+	20.6	15.3	-
	7	117	7.1	8.2	+	17.2	15.4	+
	8	112	9.4	10.6	+	13.9	20.4	-
	9	113	8.3	8.6	+	19.1	18.6	+
2-6	0	85	4.5	5.5	+	11.5	11.2	+
	4	87	5.8	5.8	+	8.7	7.1	+
	5	81	4.0	7.4	-	10.6	21.6	-
	6	75	5.7	6.1	+	11.7	8.8	-
	7	79	5.7	5.1	+	12.2	8.6	-
	8	79	6.0	7.0	+	7.4	17.0	-
	9	81	6.4	6.4	+	15.4	16.9	+
4-8	0	84	6.4	6.6	+	13.7	16.9	-
	4	85	6.5	5.9	+	8.5	7.9	+
	5	25	6.1	10.2	-	8.0	37.7	-
	6	82	5.1	7.2	-	8.2	10.1	+
	7	95	4.6	4.6	+	10.7	8.4	-
	8	95	4.1	5.7	-	7.3	14.1	-
	9	53	6.1	4.8	-	11.3	10.2	+

\+ = Agreement   Significance level 5%

\- = Disagreement

Table 27 - Result of the t-test and F-test for the two measurements of a Restitution Centre, separated according to point types and photo scales.
Number and percentages of the agreements (+) and disagreements (-) with a significance level of 5% (chapter 6.4)

Test	t or F	Scale	a - points					c - points					d - points				a-d	
			x	y	z	n_a	%	x	y	z	n_c	%	y	z	n_d	%	N	%
Student	+	1:6 000						12	10	13			9	10				
	+	1:3 500						10	12	8			10	5				
	Σ +							22	22	21	65	80	19	15	34	63	99	73
	-	1:6 000						1	3	0			4	3				
	-	1:3 500						4	2	6			4	9				
	Σ -							5	5	6	16	20	8	12	20	37	36	27
Fisher	+	1:6 000	10	9	12			9	7	8			8	4				
	+	1:3 500	10	9	11			10	11	12			9	6				
	Σ +		20	18	23	61	75	19	18	20	57	70	17	10	27	50	145	67
	-	1:6 000	3	4	1			4	6	5			5	9				
	-	1:3 500	4	5	3			4	3	2			5	8				
	Σ -		7	9	4	20	25	8	9	7	24	30	10	17	27	50	71	33

Table 28 - Result of the t-test and F-test for the two measurements of a Restitution Centre, separated according to number and percentages of the agreements (+) and disagreements (-) with a significance level of 5%
(chapter 6.4)

Restitution Centre	t		F		t+F		%	
	+	-	+	-	+	-	+	-
0	18	2	29	3	47	5	90	10
4	11	9	27	5	38	14	73	27
5	13	7	11	21	24	28	46	54
6	13	7	20	12	33	19	63	37
7	17	3	21	11	38	14	73	27
8	13	7	18	14	31	21	60	40
8	14	1	19	5	33	6	85	15
Total	99	36	145	71	244	107	70	30

Table 29 - Compilation of the ratios V_S of the standard deviations in "µm in the image" for the flights in the morning and in the afternoon (chapter 6.5)

V_S	Type of error	V_S of m_k						V_S of m_z						from table
		a	b	c	d	e	g	a	b	c	d	e	g	
34:12 (afternoon / morning)	M	1.07	1.03	0.94	-	-	0.96	0.99	1.21	0.90	-	-	0.91	14
	A	1.00	0.77	1.01	0.92		0.93	0.94	0.97	0.82	0.85	-	0.85	15
	R	1.06	0.84	1.01	0.95	1.08	0.96	0.97	0.98	0.85	0.86	0.89	0.86	17
	S	1.04	0.73	0.94	0.83	-	0.85	0.86	0.92	0.76	0.82	-	0.81	18
78:56 (afternoon / morning)	M	0.97	1.23	0.85	-	-	0.92	0.98	0.97	0.69	-	-	0.70	14
	A	1.09	1.03	1.05	0.95	-	0.97	1.27	1.25	0.89	0.94	-	0.94	15
	R	1.13	1.12	0.98	0.89	0.73	0.90	1.26	0.99	0.99	0.93	0.93	0.93	17
	S	1.28	0.79	1.09	0.98	-	1.00	1.21	1.94	0.79	1.02	-	0.98	18

Table 30 - Systematic deviations in the measuring of roof eaves caused by the operator and by the position of the sun (chapter 6.5)

Restitution	Restitution Centre	N_p	a_o cm	a_1 cm	α_o^g	$\pm n \times 200^g$	s_o cm
1	0	207	0.3	2.4	74		1.7
	1	208	3.8	2.8	95		4.3
	2	207	4.7	5.4	72		6.1
	3	199	- 3.2	3.9	102		4.2
	4	208	2.3	4.0	73		3.6
	5	130	2.9	2.4	116		3.4
	6	117	-10.4	6.7	274	- 200	11.4
	7	124	- 5.1	5.9	74		6.6
	8	127	4.2	6.3	95		6.1
	9	117	- 5.5	6.9	37		7.4
3	0	214	- 1.4	3.8	314		3.0
	1	217	- 0.6	0.5	31	+ 400	0.7
	2	214	2.1	1.9	319		2.5
	3	205	- 5.4	1.1	142	+ 200	5.5
	4	218	3.2	2.0	394		3.5
	5	234	2.2	1.1	363		2.3
	6	224	-10.7	4.8	323		11.2
	7	229	- 2.5	2.9	8	+ 400	3.2
	8	236	3.0	0.8	285		3.1
	9	217	- 3.9	3.7	10	+ 400	4.7
5	0	104	1.0	5.8	86		4.2
	4	110	0.0	6.2	81		4.4
	5	75	- 0.5	3.5	33		2.5
	6	64	- 6.4	9.1	12		9.0
	7	78	- 3.8	6.6	72		6.0
	8	74	- 1.0	4.2	98		3.1
	9	-	-	-	-		-
7	0	112	- 0.9	4.0	282		3.0
	4	116	- 2.9	1.0	83	+ 200	3.0
	5	118	- 3.6	8.2	281		6.8
	6	117	- 7.1	4.7	323		7.8
	7	122	- 1.8	2.8	81	+ 200	2.7
	8	113	0.0	2.9	297		2.1
	9	116	- 3.4	0.5	178	+ 200	3.4

Table 30 - (Continuation)

Restitution	Restitution Centre	N_p	a_o cm	a_1 cm	α_o^g	$\pm n \times 200^g$	s_o cm
2	0	127	1.1	3.2	45		2.5
	1	160	3.0	2.2	115		3.4
	2	159	3.7	2.0	181	- 200	4.0
	3	139	- 0.2	2.1	94		1.5
	4	164	1.9	2.2	46		2.5
	5	113	1.7	1.7	215	- 200	2.1
	6	142	- 6.1	2.6	180	- 200	6.4
	7	146	- 0.5	4.2	108		3.0
	8	150	2.3	3.4	138		3.3
	9	144	- 0.5	3.3	103		2.4
4	0	166	- 0.4	5.2	349		3.7
	1	169	2.5	1.0	9	+ 400	2.6
	2	169	2.2	1.0	324		2.3
	3	157	- 3.9	4.2	348		4.9
	4	170	0.2	3.9	347		2.8
	5	176	1.2	1.7	250		1.7
	6	166	- 7.0	0.5	182	+ 200	7.0
	7	176	- 0.5	1.1	362		0.9
	8	178	2.0	1.8	348		2.4
	9	173	- 1.0	2.9	379		2.3
6	0	86	0.5	2.9	29		2.1
	4	88	- 0.8	3.6	52		2.7
	5	81	2.8	2.3	73		3.2
	6	77	- 6.4	0.7	254	- 200	6.4
	7	81	- 1.0	3.1	102		2.4
	8	79	2.1	2.7	84		2.8
	9	81	- 1.6	4.0	121		3.2
8	0	84	- 1.3	5.7	337		4.2
	4	86	- 3.3	4.9	377		4.8
	5	25	2.1	9.3	275		6.9
	6	83	- 5.6	6.1	290		7.1
	7	95	- 1.6	2.0	352		2.1
	8	95	0.2	3.9	321		2.8
	9	53	- 0.7	1.9	354		1.5

Table 31 - Average values of the systematic deviations in the measuring of roof eaves and the deviation for each single restitution.
Compilation according to restitutions (chapter 6.5)

Restitution	$\bar{a}_o$	$\bar{a}_1$	$\bar{s}_o$	$\bar{a}_o$	$\bar{a}_1$	$\bar{s}_o$	$\bar{\alpha}_o^g$	m_{ao}	m_{a1}	m_{so}	m_{ao}	m_{a1}	m_{so}	$m_{\alpha o}^g$
	cm			µm				cm			µm			
1	-0.6	+3.3	5.5	-1.0	+5.5	9.1	81	5.2	3.9	2.7	8.7	6.5	4.5	22
3	-1.4	+2.0	4.0	-2.3	+3.4	6.6	359	4.4	1.8	2.8	7.3	3.0	4.7	50
2	+0.6	+1.4	3.1	+1.8	+4.1	8.9	62	2.8	2.5	1.4	8.0	7.2	3.9	57
4	-0.5	+2.2	3.1	-1.3	+6.4	8.7	350	3.0	1.8	1.7	8.5	5.2	4.9	42
5	-1.8	+5.9	4.9	-3.0	+9.8	8.1	64	2.8	2.0	2.3	4.7	3.3	3.9	34
7	-2.8	+2.2	4.1	-4.7	+3.7	6.9	303	2.1	3.8	2.3	3.5	6.3	3.8	36
6	-0.6	+2.6	3.3	-1.8	+7.3	9.3	74	3.0	1.5	1.4	8.6	4.3	4.0	32
8	-1.5	+4.8	4.2	-4.2	+13.8	12.0	329	2.5	2.6	2.2	7.1	7.4	6.4	37
12				+0.4	+4.8	9.0	72				8.4	6.9	4.2	43
34				-1.8	+4.9	7.7	354				7.9	4.2	4.8	46
56				-2.3	+8.5	8.6	69				7.1	3.9	4.0	33
78				-4.4	+8.7	9.4	317				5.6	6.9	5.3	37
1256				-0.7	+6.3	8.8	71				7.9	5.9	4.1	40
3478				-2.9	+6.4	8.4	339				7.1	5.4	5.0	43

Table 32 - Systematic deviations in the measuring of roof eaves. Compilation according to Restitution Centres. Mean values of four restitutions each carried out by the same operator and the mean deviation of the single restitution in "μm in the image"

Restitution	Restitution Centre	a_o'	a_1'	s_o'	m_{ao}	m_{a1}	m_{so}
1324 (1^{st} oper.)	0	0.0	8.6	6.4	2.4	4.7	3.3
	1	+5.3	3.7	6.4	4.3	2.3	3.6
	2	+7.0	2.4	8.1	3.0	6.0	3.4
	3	-6.5	5.7	8.6	4.6	5.7	4.1
	4	+3.8	6.9	6.7	2.2	3.3	1.1
	5	+4.2	1.5	5.1	0.7	4.3	1.0
	6	-18.1	-3.0	19.0	1.3	8.4	0.7
	7	-3.9	7.4	6.9	3.3	4.1	3.7
	8	+6.1	6.7	7.9	0.9	4.3	2.4
	9	-5.0	8.8	8.4	3.5	2.2	2.6
	0 to 9	-0.7	4.9	8.4	2.9	4.9	2.8
	1)				1.4	2.4	1.4
	2)				7.8	3.7	3.9
5768 (2^{nd} oper.)	0	-0.5	10.2	7.5	2.6	4.2	3.1
	4	-4.1	8.3	8.4	4.0	6.8	3.8
	5	+1.8	13.1	11.1	6.4	9.6	6.4
	6	-14.1	9.6	16.7	3.6	8.8	3.3
	7	-4.2	5.2	6.9	1.6	6.9	2.2
	8	+1.2	7.7	6.2	3.3	2.6	2.2
	9	-4.1	5.3	6.4	1.9	6.1	2.4
	0 to 9	-3.4	8.5	9.0	3.7	6.8	3.6
	1)				1.8	3.4	1.8
	2)				5.4	2.8	3.8
1324 - 5768 (1^{st} - 2^{nd} oper.)	3)				2.8	4.5	1.9

1) Mean deviations of the mean values a_o', a_1' and s_o' obtained from deviations of the four single values a_o, a_1 and s_o as compared to the mean values.

2) Mean deviations of the mean values a_o', a_1' and s_o' obtained from deviations of these ten and seven values respectively as compared to the overall mean $\bar{a}_o$, $\bar{a}_1$ and $\bar{s}_o$ respectively.

3) Mean deviations of the mean values a_o', a_1' and s_o' obtained from the seven differences of the values for the two operators of a Restitution Centre.

Table 33 - Dispersion of the systematic deviations of roof eaves from differences of two measurements carried out by the same operator and of the measurements made by different operators in "μm in the image" (chapter 6.5)

	Restitution	$\bar{d}a_o$	$\bar{d}a_1$	$\bar{d}s_o$	m_{ao}	m_{a1}	m_{so}
1^{st} oper.	1-3	+1.3	+2.1	+2.7	2.5	5.7	2.7
	2-4	+3.2	-2.3	-1.0	3.0	4.5	3.0
		+2.2	-0.1	+0.9	2.8	5.1	2.9
2^{nd} oper.	5-7	+1.5	+5.2	+1.0	2.5	6.3	2.9
	6-8	+2.4	-6.4	-2.7	3.0	8.1	3.9
		+2.0	-0.6	-0.9	2.9	7.3	3.4
1^{st} and 2^{nd} oper.	1-5	+3.5	-5.9	+1.0	3.8	7.9	2.3
	3-7	+2.3	+0.9	+0.9	4.4	4.8	4.5
	2-6	+4.0	+1.8	-1.4	4.2	3.7	0.7
	4-8	+2.0	-7.2	-3.5	3.5	8.0	4.4
		+3.0	-2.6	-0.8	4.0	6.4	3.4

Table 34 - Compilation of some standard errors (chapter 7.1)

Point type	a	b	c	d	e	g	from table	g : a
				Terrestrial measurement				
N_M	1250	114	390	1474	-	1979	6	-
N_P	261	23	81	300	-	404	6	-
				m_k in cm in the terrain				
T	1.3	2.9		2.1	-	2.1	6	1.60
				m_z in cm in the terrain				
T	1.3	4.6	1.9	2.7	-	2.7	6	2.10
				Photogrammetric measurement				
N_M	5801	189	1890	6996	(1698)	$9075^{x)}$	15,17,18	-
N_P	910	39	294	1094	(332)	$1427^{x)}$	15,17,18	-
				m_k in µm in the image				
M	3.0	7.5	5.0	-	-	5.0	14	1.75
A	5.5	23	18	17	-	17	15	3.15
R	3.5	20	15	15	9	14	17	3.80
S	3.0	16	13	11	-	11	18	3.85
				m_z in µm in the image				
M	8.5	10	11	-	-	11	14	1.30
A	15	23	31	31	-	31	15	2.00
R	12	22	29	28	28	28	17	2.45
S	8.5	14	19	21	-	21	18	2.40

x) without number of the e-points

Table 35 - Compilation of the ratios V_k and V_z of some standard errors (chapter 7.1)

Point type	a	b	c	d	g	from table
			V_k of m_k in µm in the image			
V_M	1.20	1.10	0.95	1.05	1.05	23
V_B	1.05	0.95	1.35	1.05	1.05	24
V_S	1.00	0.75	1.00	0.90	0.95	29
			V_z of m_z in µm in the image			
V_M	1.35	1.20	1.15	1.20	1.20	23
V_B	1.05	1.40	1.05	1.10	1.10	24
V_S	0.95	0.95	0.80	0.85	0.85	29

V_M = photo scale 1:3 500 : photo scale 1:6 000

V_B = 2nd operator : 1st operator

V_S = afternoon flights : morning flights

Table 36 - Standard errors in "µm in the image" taken from some international tests (chapter 7.2)

Test	Date	Photo scale	m_x M	m_x A	m_x R	m_x S	m_z M	m_z A	m_z R	m_z S	Remarks
(1) signalised points											
Oberriet	1954 - 1956	1:4 700	-	13	5	-	-	25	-	-	film
SIP		1:6 000 - 1:15 600	-	9	5	-	-	20	-	-	plates
Oberriet	1958 - 1959	1:4 700 - 1:12 500	5	14	6	-	11	33	-	-	film
OEEPE		1:6 000 - 1:15 600		10	5	-		24	-	-	plates
Reichenbach	1969	1:8 000 - 1:12 000	3.2	11	8	7	7	26	20	14	analogue instruments stereo comparators
OEEPE		1:8 000 - 1:12 000	1.5	7	-	-	-	22	-	-	
Wien	1980	1:1 500 - 1: 4 000	-	8.5	7	6.5	-	25	20	19	
Dordrecht	1980	1:3 500 - 1: 6 000	3	5.5	3.5	3	8.5	15	12	8.5	
(2) non-signalised points											
accord. to [1]	1955 - 1970	1:2 400 - 1: 9 500	-	20	-	-	-	-	-	-	different authors
Oberriet	1975	1:4 700 - 1: 6 000	-	46	-	-	-	-	-	-	
OEEPE		1:8 600 - 1:10 000	-	25	-	-	-	-	-	-	
Wien	1980	1:1 500 - 1: 4 000	-	41	29	31	-	72	57	54	building points
Dordrecht	1980	1:3 500 - 1: 6 000	5	17	14	11	11	31	28	21	

LIST OF THE OEEPE PUBLICATIONS

State – November 1982

A. Official publications

1 *Trombetti, C.:* „Activité de la Commission A de l'OEEPE de 1960 à 1964" – *Cunietti, M.:* „Activité de la Commission B de l'OEEPE pendant la période septembre 1960–janvier 1964" – *Förstner, R.:* „Rapport sur les travaux et les résultats de la Commission C de l'OEEPE (1960–1964)" – *Neumaier, K.:* „Rapport de la Commission E pour Lisbonne" – *Weele, A.J. v. d.:* „Report of Commission F." – Frankfurt a. M. 1964, 50 pages with 7 tables and 9 annexes.

2 *Neumaier, K.:* „Essais d'interprétation de »Bedford« et de »Waterbury«. Rapport commun établi par les Centres de la Commission E de l'OEEPE ayant participé aux tests" – „The Interpretation Tests of »Bedford« and »Waterbury«. Common Report Established by all Participating Centres of Commission E of OEEPE" – „Essais de restitution »Bloc Suisse«. Rapport commun établi par les Centres de la Commission E de l'OEEPE ayant participé aux tests" – „Test »Schweizer Block«. Joint Report of all Centres of Commission E of OEEPE." – Frankfurt a. M. 1966, 60 pages with 44 annexes.

3 *Cunietti, M.:* „Emploi des blocs de bandes pour la cartographie à grande échelle – Résultats des recherches expérimentales organisées par la Commission B de l'O.E.E.P.E. au cours de la période 1959–1966" – „Use of Strips Connected to Blocks for Large Scale Mapping – Results of Experimental Research Organized by Commission B of the O.E.E.P.E. from 1959 through 1966." – Frankfurt a. M. 1968, 157 pages with 50 figures and 24 tables.

4 *Förstner, R.:* „Sur la précision de mesures photogrammétriques de coordonnées en terrain montagneux. Rapport sur les résultats de l'essai de Reichenbach de la Commission C de l'OEEPE" – „The Accuracy of Photogrammetric Co-ordinate Measurements in Mountainous Terrain. Report on the Results of the Reichenbach Test Commission C of the OEEPE." – Frankfurt a. M. 1968, Part I: 145 pages with 9 figures; Part II: 23 pages with 65 tables.

5 *Trombetti, C.:* „Les recherches expérimentales exécutées sur de longues bandes par la Commission A de l'OEEPE." – Frankfurt a. M. 1972, 41 pages with 1 figure, 2 tables, 96 annexes and 19 plates.

6 *Neumaier, K.:* „Essai d'interprétation. Rapports des Centres de la Commission E de l'OEEPE." – Frankfurt a. M. 1972, 38 pages with 12 tables and 5 annexes.

7 *Wiser, P.:* „Etude expérimentale de l'aérotriangulation semi-analytique. Rapport sur l'essai »Gramastetten«." – Frankfurt a. M. 1972, 36 pages with 6 figures and 8 tables.

8 „Proceedings of the OEEPE Symposium on Experimental Research on Accuracy of Aerial Triangulation (Results of Oberschwaben Tests)"
Ackermann, F.: „On Statistical Investigation into the Accuracy of Aerial Triangulation. The Test Project Oberschwaben" — „Recherches statistiques sur la précision de l'aérotriangulation. Le champ d'essai Oberschwaben" — *Belzner, H.:* „The Planning. Establishing and Flying of the Test Field Oberschwaben" — *Stark, E.:* Testblock Oberschwaben, Programme I. Results of Strip Adjustments" — *Ackermann, F.:* „Testblock Oberschwaben, Program I. Results of Block-Adjustment by Independent Models" — *Ebner, H.:* Comparison of Different Methods of Block Adjustment" — *Wiser, P.:* „Propositions pour le traitement des erreurs non-accidentelles" — *Camps, F.:* „Résultats obtenus dans le cadre du project Oberschwaben 2A" — *Cunietti, M.; Vanossi, A.:* „Etude statistique expérimentale des erreurs d'enchaînement des photogrammes" — *Kupfer, G.:* „Image Geometry as Obtained from Rheidt Test Area Photography" — *Förstner, R.:* „The Signal-Field of Baustetten. A Short Report" — *Visser, J.; Leberl, F.; Kure, J.:* „OEEPE Oberschwaben Reseau Investigations" — *Bauer, H.:* „Compensation of Systematic Errors by Analytical Block Adjustment with Common Image Deformation Parameters." — Frankfurt a. M. 1973, 350 pages with 119 figures, 68 tables and 1 annex.

9 *Beck, W.:* „The Production of Topographic Maps at 1 : 10,000 by Photogrammetric Methods. — With statistical evaluations, reproductions, style sheet and sample fragments by Landesvermessungsamt Baden-Württemberg, Stuttgart." — Frankfurt a. M. 1976, 89 pages with 10 figures, 20 tables and 20 annexes.

10 „Résultats complémentaires de l'essai d'«Oberriet» de la Commission C de l'OEEPE — Further Results of the Photogrammetric Tests of «Oberriet» of the Commission C of the OEEPE"
Härry, H.: „Mesure de points de terrain non signalisés dans le champ d'essai d'«Oberriet» — Measurements of Non-Signalized Points in the Test Field «Oberriet» (Abstract)" — *Stickler, A.; Waldhäusl, P.:* „Restitution graphique des points et des lignes non signalisés et leur comparaison avec des résultats de mesures sur le terrain dans le champ d'essai d'«Oberriet» — Graphical Plotting of Non-Signalized Points and Lines, and Comparison with Terrestrial Surveys in the Test Field «Oberriet»" — *Förstner, R.:* „Résultats complémentaires des transformations de coordonnées de l'essai d'«Oberriet» de la Commission C de l'OEEPE — Further Results from Co-ordinate Transformations of the Test «Oberriet» of Commission C of the OEEPE" — *Schürer, K.:* „Comparaison des distances d'«Oberriet» — Comparison of Distances of «Oberriet» (Abstract)." — Frankfurt a. M. 1975, 158 pages with 22 figures and 26 tables.

11 „25 années de l'OEEPE"
Verlaine, R.: „25 années d'activité de l'OEEPE" — „25 Years of OEEPE (Summary)" — *Baarda, W.:* „Mathematical Models." — Frankfurt a. M. 1979, 104 pages with 22 figures.

12 *Spiess, E.:* „Revision of 1 : 25,000 Topographic Maps by Photogrammetric Methods" (in preparation).

B. Special publications

— Special Publications O.E.E.P.E. — Number I

Solaini, L.; Trombetti, C.: Relation sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). I[ère] Partie: Programme et organisation du travail. — *Solaini, L.; Belfiore, P.:* Travaux préliminaires de la Commission B de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.) (Triangulations aériennes aux grandes échelles). — *Solaini, L.; Trombetti, C.; Belfiore, P.:* Rapport sur les travaux expérimentaux de triangulation aérienne exécutés par l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (Commission A et B). — *Lehmann, G.:* Compte rendu des travaux de la Commission C de l'O.E.E.P.E. effectués jusqu'à présent. — *Gotthardt, E.:* O.E.E.P.E. Commission C. Compte-rendu de la restitution à la Technischen Hochschule, Stuttgart, des vols d'essai du groupe I du terrain d'Oberriet. — *Brucklacher, W.:* Compte-rendu du centre «Zeiss-Aerotopograph» sur les restitutions pour la Commission C de l'O.E.E.P.E. (Restitution de la bande de vol, groupe I, vol. No. 5). — *Förstner, R.:* O.E.E.P.E. Commission C. Rapport sur la restitution effectuée dans l'Institut für Angewandte Geodäsie, Francfort sur le Main. Terrain d'essai d'Oberriet les vols No. 1 et 3 (groupe I). — I.T.C., Delft: Commission C, O.E.E.P.E. Déroulement chronologique des observations. — Photogrammetria XII (1955—1956) 3, Amsterdam 1956, pp. 79—199 with 12 figures and 11 tables.

— Publications spéciales de l'O.E.E.P.E. — Numéro II

Solaini, L.; Trombetti, C.: Relations sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). 2[e] partie. Prises de vues et points de contrôle. — *Gotthardt, E.:* Rapport sur les premiers résultats de l'essai d'«Oberriet» de la Commission C de l'O.E.E.P.E. — Photogrammetria XV (1958—1959) 3, Amsterdam 1959, pp. 77—148 with 15 figures and 12 tables.

— *Trombetti, C.:* Travaux de prises de vues et préparation sur le terrain effectuées dans le 1958 sur le nouveau polygone italien pour la Commission A de l'OEEPE. — Florence 1959, 16 pages with 109 tables.

— *Trombetti, C.; Fondelli, M.:* Aérotriangulation analogique solaire. — Firence 1961, 111 pages, with 14 figures and 43 tables.

— Publications spéciales de l'O.E.E.P.E. — Numéro III

Solaini, L.; Trombetti, C.: Rapport sur les résultats des travaux d'enchaînement et de compensation exécutés pour la Commission A de l'O. E. E. P. E. jusqu'au mois de Janvier 1960. Tome 1: Tableaux et texte. Tome 2: Atlas. — Photogrammetria XVII (1960—1961) 4, Amsterdam 1961, pp. 119—326 with 69 figures and 18 tables.

– „OEEPE – Sonderveröffentlichung Nr. 1"

Gigas, E.: „Beitrag zur Geschichte der Europäischen Organisation für photogrammetrische experimentelle Untersuchungen" – *N. N.:* „Vereinbarung über die Gründung einer Europäischen Organisation für photogrammetrische experimentelle Untersuchungen" – „Zusatzprotokoll" – *Gigas, E.:* „Der Sechserausschuß" – *Brucklacher, W.:* „Kurzbericht über die Arbeiten in der Kommission A der OEEPE" – *Cunietti, M.:* „Kurzbericht des Präsidenten der Kommission B über die gegenwärtigen Versuche und Untersuchungen" – *Förstner, R.:* „Kurzbericht über die Arbeiten in der Kommission B der OEEPE" – „Kurzbericht über die Arbeiten in der Kommission C der OEEPE" – *Belzner, H.:* „Kurzbericht über die Arbeiten in der Kommission E der OEEPE" – *Schwidefsky, K.:* „Kurzbericht über die Arbeiten in der Kommission F der OEEPE" – *Meier, H.-K.:* „Kurzbericht über die Tätigkeit der Untergruppe „Numerische Verfahren" in der Kommission F der OEEPE" – *Belzner, H.:* „Versuchsfelder für internationale Versuchs- und Forschungsarbeiten." – Nachr. Kt.- u. Vermesss.-wes., R. V, Nr. 2, Frankfurt a. M. 1962, 41 pages with 3 tables and 7 annexes.

– *Rinner, K.:* Analytisch-photogrammetrische Triangulation eines Teststreifens der OEEPE. – Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. Nr. 1, Wien 1962, 31 pages.

– *Neumaier, K.; Kasper, H.:* Untersuchungen zur Aerotriangulation von Überweitwinkelaufnahmen. – Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. Nr. 2, Wien 1965, 4 pages with 4 annexes.

– „OEEPE – Sonderveröffentlichung Nr. 2"

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– „OEEPE – Sonderveröffentlichung Nr. 3"

Neumaier, K.: „Versuch »Bedford« und »Waterbury«. Gemeinsamer Bericht aller Zentren der Kommission E der OEEPE" – „Versuch »Schweizer Block«. Gemeinsamer Bericht aller Zentren der Kommission E der OEEPE." – Nachr. Kt.- u. Vermess.-wes., R. V, Nr. 13, Frankfurt a. M. 1966, 30 pages with 44 annexes.

– *Stickler, A.; Waldhäusl, P.:* Interpretation der vorläufigen Ergebnisse der Versuche der Kommission C der OEEPE aus der Sicht des Zentrums Wien. – Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. (Publ. Spéc.) Nr. 3, Wien 1967, 4 pages with 2 figures and 9 tables.

– „OEEPE – Sonderveröffentlichung Nr. 4"

Schürer, K.: „Die Höhenmeßgenauigkeit einfacher photogrammetrischer Kartiergeräte. Bemerkungen zum Versuch »Schweizer Block« der Kommission E der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M., 1968, 25 pages with 7 figures and 3 tables.

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Knorr, H.: „Die Europäische Organisation für experimentelle photogrammetrische Untersuchungen – OEEPE – in den Jahren 1962 bis 1970." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1971, 44 pages with 1 figure and 3 tables.

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Neumaier, K.: „Interpretationsversuch. Berichte der Zentren der Kommission E der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1972, 33 pages with 12 tables and 5 annexes.

– „OEEPE – Sonderveröffentlichung Nr. D–9"

Beck, W.: „Herstellung topographischer Karten 1 : 10 000 auf photogrammetrischem Weg. Mit statistischen Auswertungen, Reproduktionen, Musterblatt und Kartenmustern des Landesvermessungsamts Baden-Württemberg, Stuttgart." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1976, 65 pages with 10 figures, 20 tables and 20 annexes.

– „OEEPE – Sonderveröffentlichung Nr. D–10"

Weitere Ergebnisse des Meßversuchs „Oberriet" der Kommission C der OEEPE. *Härry, H.:* „Messungen an nicht signalisierten Geländepunkten im Versuchsfeld «Oberriet»" – *Stickler, A.; Waldhäusl, P.:* „Graphische Auswertung nicht signalisierter Punkte und Linien und deren Vergleich mit Feldmessungsergebnissen im Versuchsfeld «Oberriet»" – *Förstner, R.:* „Weitere Ergebnisse aus Koordinatentransformationen des Versuchs «Oberriet» der Kommission C der OEEPE" – *Schürer, K.:* „Streckenvergleich «Oberriet»." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1975, 116 pages with 22 figures and 26 tables.

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- „OEEPE — Sonderveröffentlichung Nr. D-13"

  Haug, G.: „Bestimmung und Korrektur systematischer Bild- und Modelldeformationen in der Aerotriangulation am Beispiel des Testfeldes „Oberschwaben." — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1980, 136 pages with 25 figures and 51 tables.

C. Congress reports and publications in scientific reviews

- *Stickler, A.:* Interpretation of the Results of the O.E.E.P.E. Commission C. — Photogrammetria XVI (1959—1960) 1, pp. 8—12, 3 figures, 1 annexe (en langue allemande: pp. 12—16).
- *Solaini, L.; Trombetti, C.:* Results of Bridging and Adjustment Works of the Commission A of the O.E.E.P.E. from 1956 to 1959. — Photogrammetria XVI (1959—1960) 4 (Spec. Congr.-No. C), pp. 340—345, 2 tables.
- *N. N.:* Report on the Work Carried out by Commission B of the O.E.E.P.E. During the Period of September 1956—August 1960. — Photogrammetria XVI (1959—1960) 4 (Spec. Congr.-No. C), pp. 346—351, 2 tables.
- *Förstner, R.:* Bericht über die Tätigkeit und Ergebnisse der Kommission C der O.E.E.P.E. (1956—1960). — Photogrammetria XVI (1959—1960) 4 (Spec. Congr.-No. C), pp. 352—357, 1 table.
- *Bachmann, W. K.:* Essais sur la précision de la mesure des parallaxes verticales dans les appareils de restitution du I^{er} ordre. — Photogrammetria XVI (1959—1960) 4 (Spec. Congr.-No. C), pp. 358—360).
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- *Cunietti, M.:* L'erreur de mesure des parallaxes transversales dans les appareils de restitution. — Bull. Trimestr. Soc. Belge Photogramm., No. 66, Décembre 1961, pp. 3—50, 12 figures, 22 tables.

- „OEEPE — Arbeitsberichte 1960/64 der Kommissionen A, B, C, E, F"

  Trombetti, C.: „Activité de la Commission A de l'OEEPE de 1960 à 1964" — *Cunietti, M.:* „Activité de la Commission B de l'OEEPE pendant la période septembre 1960—janvier 1964" — *Förstner, R.:* „Rapport sur les travaux et les résultats de la Commission C de l'OEEPE (1960—1964)" — *Neumaier, K.:* „Rapport de la Commission E pour Lisbonne" — *Weele, A.J. van der:* „Report of Commission F." — Nachr. Kt.- u. Vermess.-wes., R. V. Nr. 11, Frankfurt a. M. 1964, 50 pages with 7 tables and 9 annexes.
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- *Gotthardt E.:* Die Tätigkeit der Kommission B der OEEPE. — Bildmess. u. Luftbildwes. 36 (1968) 1, pp. 35—37.
- *Cunietti, M.:* Résultats des recherches expérimentales organisées par la Commission B de l'OEEPE au cours de la période 1959—1966. Résumé du Rapport final. — Présenté à l'XI^{e} Congrès International de Photogrammétrie, Lausanne 1968, Comm. III (en langues française et anglaise), 9 pages.

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- *Timmerman, J.:* Proef „OEEPE-Dordrecht". – ngt 74, 4. Jg., Nr. 6, Juni 1974, S. 143–154 (Kurzfassung: Versuch „OEEPE-Dordrecht". Genauigkeit photogrammetrischer Gebäudevermessung. Vorgelegt auf dem Symposium der Kommission IV der I.G.P., Paris, 24.–26. September 1974).
- *Timmerman, J.:* Report on the Commission C. "OEEPE-Dordrecht" Experiment. – Presented Paper for Comm. IV, XIII[th] Congress of ISP, Helsinki 1976.
- *Verlaine, R.:* La naissance et le développement de l'OEEPE – Festschrift – Dr. h. c. *Hans Härry*, 80 Jahre – Schweizerische Gesellschaft für Photogrammetrie und Wild Heerbrugg AG, Bern 1976.
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- *Baj, E.; Cunietti, M.; Vanossi, A.:* Détermination Expérimentale des Erreurs Systématiques des Faisceaux Perspectifs. – Société Belge de Photogrammétrie, Bulletin trimestriel, Brüssel 1977, pp 21–49.
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- *Waldhäusl, P.:* Der Versuch Wien der OEEPE/C. – Geowissenschaftliche Mitteilungen der Studienrichtung Vermessungswesen der TU Wien, Heft 13, Wien 1978, pp. 101–124.
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