

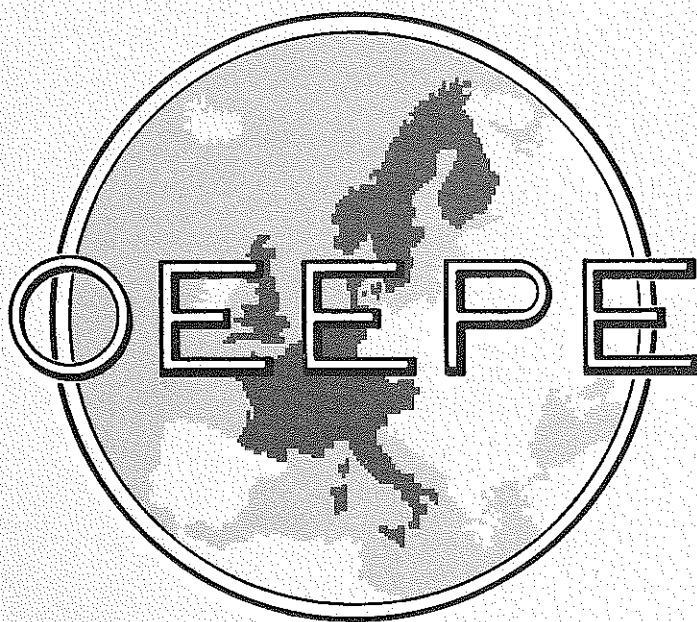
November 1987

EUROPEAN ORGANIZATION FOR EXPERIMENTAL PHOTOGRAMMETRIC RESEARCH

SPACELAB METRIC CAMERA EXPERIMENT

TEST OF IMAGE ACCURACY

Report by I. J. Dowman and G. Ducher



Official Publication N° 19

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Spacelab Metric Camera Experiment

Test of Image Accuracy

(with 13 Figures, 25 Tables and 7 Appendices)

Report by I. J. Dowman and G. Ducher

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Spacelab Metric Camera Experiment

Test of Image Accuracy

Report by I.J. Dowman and G. Ducher

ABSTRACT: The metric camera experiment on the first flight of the Spacelab module on the space shuttle produced a large number of photographs taken with a calibrated photogrammetric camera. The OEEPE has conducted an experiment to test the accuracy of this photography using a test area in Southern France. Two models, one with 60 % overlap and one with 20 % overlap, were tested using 22 control points and 43 check points. The results from 11 centres around Europe have been analysed and a report on the analysis is given.

The conclusions from the test indicate that accuracies of between 20 m and 30 m can be obtained in all three co-ordinate directions but that there is evidence of systematic error possibly due to the effect of refraction. There is also no doubt that the type and accuracy of control affects the results. Some conclusions are made regarding the best type of control point to use. Results also indicate that better accuracies may be obtained if projection co-ordinates, rather than geocentric co-ordinates are used.

RÉSUMÉ: Dans le cadre de l'expérience Caméra Métrique réalisée lors du 1er vol du laboratoire Spacelab à bord de la navette spatiale, un grand nombre de photographies ont été prises avec une chambre photogrammétrique étalonnée. L'OEEPE a exécuté un essai afin d'examiner la précision obtenue par ces photographies en se servant d'un polygone d'essai situé dans le sud de la France. Deux modèles dont l'un avec un recouvrement de 60 % et l'autre de 20 % ont été examinés en utilisant 22 points d'appui et 43 points de vérification, sélectionnés dans un catalogue de 200 points identifiables, établi par l'IGN (F). Les résultats obtenus par les 11 centres de restitution, répartis à travers l'Europe, sont analysés et fournis dans ce rapport.

Les conclusions tirées de cet essai indiquent que l'on peut obtenir des précisions comprises entre 20 m et 30 m dans les trois coordonnées, bien que des erreurs systématiques aient été constatées, probablement dues à l'influence de la réfraction atmosphérique. De plus, il n'y a pas de doute que la nature et la précision du canevas de restitution influencent les résultats.

L'un des principaux problèmes rencontrés fut en effet d'identifier les points de canevas. Les résidus sont considérablement supérieurs à la valeur que l'on pourrait théoriquement attendre et le nombre de grosses erreurs que l'on a trouvé est également supérieur à la normale. De nombreux opérateurs se sont plaints de difficultés d'identification, ce qui n'a pas manqué de détériorer la précision finale.

De plus la date du vol de Spacelab, effectué début décembre 1983, n'était pas des plus favorable à une bonne restitution photogrammétrique, même si ce vol a permis de montrer la faisabilité de saisies spatiales de qualité.

L'analyse des résultats a montré également que la précision altimétrique s'améliorait nettement, sans atteindre un rapport de 2 toutefois, lorsque l'on utilisait des recouvrements à 20 %, pour restituer les couples dont le rapport B/H atteint alors 0,6 au lieu de 0,3.

Quelques considérations sur la nature des meilleurs points de canevas à retenir sont fournies; elles mettent en évidence une facilité d'identification bien supérieure pour les points dont la définition est liée au thème de l'eau ou à celui de la végétation, tandis qu'il semble que les points choisis sur les sommets aient les résidus les plus petits.

Enfin il est apparu que les résultats étaient en général meilleurs lorsque l'on travaillait dans le système des coordonnées de la projection conforme de Lambert plutôt que dans celui des coordonnées géocentriques.

ZUSAMMENFASSUNG: Während des 1. Fluges des Spacelab-Labors an Bord der Raumfähre wurden im Rahmen des Versuchs mit der metrischen Kamera sehr viele Aufnahmen mit einer kalibrierten photogrammetrischen Kamera gemacht. Die OEEPE hat einen Versuch mit dem Ziel der Überprüfung der Genauigkeit dieses Aufnahmematerials durchgeführt, für welchen man ein Testgebiet im Süden Frankreichs ausgesucht hatte. Zwei Modelle, eines mit 60 % Überlappung und eines mit 20 % Überlappung, sind unter Einbeziehung von 22 Paßpunkten sowie von 43 Kontrollpunkten entsprechend untersucht worden. Sie wurden aus einem vom IGN (F) aufgestellten Katalog von 200 identifizierbaren Punkten ausgewählt. Es werden die von den 11 über Europa verteilten Auswertezentren erzielten Ergebnisse analysiert und in diesem Bericht zusammengestellt.

Die bei diesem Versuch gewonnenen Erkenntnisse machen deutlich, daß in allen drei Koordinatenrichtungen Genauigkeiten zwischen 20 m und 30 m erzielt werden können; doch sind in der Analyse auch systematische Abweichungen nachgewiesen, die möglicherweise dem Refraktionseffekt zuzuordnen sind. Es werden auch keinerlei Zweifel an der Tatsache gelassen, daß Art und Genauigkeit der Paßpunkte auf die Ergebnisse von Einfluß sind.

Eines der Hauptprobleme war in der Tat die Paßpunktbestimmung. Die Restfehler liegen beträchtlich über den Werten, die theoretisch zu erwarten waren, und die Anzahl der groben Fehler liegt ebenfalls über dem Normalwert. Zahlreiche Auswerter haben sich über Identifizierungsschwierigkeiten beklagt, was nicht ohne negativen Einfluß auf die Endgenauigkeit blieb.

Überdies lag der Flugtermin von Spacelab von Anfang Dezember 1983 nicht sehr günstig für eine gute photogrammetrische Auswertung, auch wenn mit diesem Flug gezeigt werden konnte, daß Weltraumaufnahmen von guter Qualität realisierbar sind.

Die Ergebnisanalyse hat auch gezeigt, daß die Höhengengenauigkeit deutlich besser war, ohne jedoch den Faktor 2 zu erreichen, wenn Überlappungen von 20 % verwendet wurden, um Bildpaare auszuwerten, deren B/H-Verhältnis dann 0,6 statt 0,3 beträgt.

Es folgen einige Betrachtungen darüber, wie die am besten zu benutzenden Paßpunkte beschaffen sein sollten; hierbei wird herausgestellt, daß die Identifizierung leichter ist bei Punkten, die an die Gewässer- oder Vegetationsthematik gebunden sind, während offenbar die auf Spitzen und Gipfeln gelegenen Punkte die kleinsten Restfehler aufweisen.

Schließlich konnte man im allgemeinen bessere Ergebnisse erzielen, wenn man im Koordinatensystem der konformen Lambert-Projektion arbeitete als mit geozentrischen Koordinaten.

1 Introduction

The use of a photogrammetric camera from space has been planned for many years. In Europe the first opportunity came with the development of the Spacelab module, constructed by the European Space Agency (ESA), for use in the American space shuttle. It was announced in 1977 that a Zeiss RMK A 30/23 camera would be flown on the first Spacelab mission and that the photographs from that mission would be available for evaluation by the photogrammetric community. An ESA Metric Camera Working group was then set up to advise ESA and manage this experiment. The OEEPE responded to the announcement of opportunity by submitting three proposals, one from each of commissions A, D and E. During the period between the announcement of opportunity and the launch of Spacelab in November 1983, the OEEPE Steering Committee set up an Action Group on the use of satellite data to coordinate OEEPE activities in this area. The action group proposed a series of experiments covering image content, image accuracy, map compilation and revision, orthophoto production and aerial triangulation. After the mission, on inspection of the photographs, it was decided not to proceed with the test of image content because of the rather poor resolution of the images; the test on map compilation and revision of metric camera photography was replaced with a similar test of large format camera photography; the tests on orthophoto production and aerial triangulation have been abandoned. This report covers the test of image accuracy.

The objective of the test is to investigate the geometry of the photographs as thoroughly as possible. A large number of control points are used which have been derived from fieldwork and from 1 : 25,000 maps, this part of the work was carried out by IGN in Paris and is described in chapter 3. The control was provided in both a geocentric system and a projection system (Lambert Conformal) and participants were required to set the models up so as to remove any distortions. Participants were required to produce a set of ground control co-ordinates of test points and to provide details of their setting up procedure. Two models were tested, both of the area around Marseilles in SE France, one with 60 % overlap and one with 20 % overlap.

11 centres participated, using 5 different types of instrument. University College London acted as the pilot centre. A full description of the test and of the results are presented in this report.

2 The Metric Camera Experiment on Spacelab and the OEEPE Test

2.1 *The metric camera experiment on Spacelab*

The background and details of the metric camera experiment on Spacelab have been described frequently. A good overview related to photogrammetry was given by *Ducher* (1980). The basic facts of the mission and the camera are as follows:

Mission:

Shuttle flight:	STS-9 28th Nov.—8th Dec. 1983
Altitude:	244—250 km
Inclination:	57°

Camera:

Type:	Zeiss RMK A 30/23, modified for use in Spacelab
Principal distance:	305.128 mm
Format:	230 mm x 230 mm
Film:	Kodak Double X Aerographic Film 2405 Kodak Aerochrome Infrared Colour 2443

The results of the mission were discussed at the Metric Camera Workshop in February 1985 (ESA 1985) at which results of many tests were given. The accuracy results given at that meeting have been summarised by *Dowman* (1985) as follows:

A summary of photogrammetric results is presented in tables 2.1 and 2.2. It can be seen that, in general, planimetric accuracy of setting up single models was between 20 m and 30 m and height accuracy was about the same. An exception was the result of *Togliatti* which may be explained by her use of control points with surveyed co-ordinates. Most workers had used control taken from maps of 1 : 25,000 or 1 : 50,000 scale and there seemed to be a correlation between results and quality of control. More care will have to be taken with control in future work. Several people also commented on the poor quality of some of the photographs and this too must have affected accuracy. These problems arise from the different nature of space photography which covers large areas, often over different map series on different datums, together with there being no chance to be able to repeat the photography on the grounds of poor quality. Few speakers reported on results of plotting, possibly due to poor photographic quality. The amount of detail which could be plotted falls far short of that required even for mapping at 1 : 100,000 scale. Results of contouring were also generally disappointing although again *Togliatti* showed impressive results. The small amount of work which had been done on digital elevation models and orthophotography was over limited areas and results were inconclusive.

The general conclusion from the photogrammetric work was that theoretical accuracy was achieved but that the potential for map compilation was not as good as had been hoped. This latter conclusion is tempered by knowledge of the poor photographic conditions at the time of flight, particularly on strip 25 over Europe which was used by many workers, by the excellent quality of the images from the NASA Large Format Camera seen at the meeting and by the expectation of better things from the Metric Camera with forward motion compensation.

Since 1985 other tests have been completed which generally confirm the results reported above. Of particular interest are results from aerial triangulation using bundle adjustment carried out by *Engel* et al. (1986) with control taken from 1 : 5000 scale maps and estimated to have an accuracy of ± 3 m. Results without additional parameters indicate planimetric accuracies of less than 10 m and elevation accuracies of about 30 m. Use of projection co-ordinates and adjustment of image coordinates for effect of earth curvature reduces planimetric accuracies to less than 5 m and elevation to 11 m.

Table 2.1 — Summary of results from orientation and plotting of single models

Participant (equipment)	Accuracy (location)	Plotting	Control point quality
<i>Adhikary</i> (Kern PG3)	< 12 m in Z 5 points (Himalayas)	100 m contours Good fit to existing map	Peaks good
<i>Bähr</i> (Zeiss (Jena) Topocart B)	Small areas X, Y 20 m—50 m Z 20 m (Germany)	100 m contours Fit not too good Shape only	
<i>Dowman</i> (Kern DSR 1)	X, Y 20 m—30 m Z 25 m (France, Libya)	Insufficient detail for 1 : 100,000 maps	
<i>Lummaux</i> (Matra Traster)	—	100 m contours	Peaks and river features good
<i>Stark</i> (Zeiss (Oberkochen) Planicomp)	r. m. s. e. Z 22 m from DEM (Germany)	100 m contours Not good comparison	
<i>Togliatti</i> (Zeiss (Oberkochen) Planicomp)	X, Y 12 m Z 22 m 1500 check points in height (Italy)	100 m contours Good fit	

Table 2.2 — Summary of results of aerial triangulation and orthophotography production

	Aerial triangulation	Orthophotographs
<i>Ackermann</i>	X, Y 39 m Z 28 m—44 m 5 models, 65 points	
<i>Jansa</i>	X, Y 7 m Z 30 m	X, Y 0.2 mm Z 80 m Slit size a limiting factor
<i>Konecny</i>		10 m relative accuracy
<i>Lummaux</i>		Good agreement of contours

2.2 *The OEEPE test*

2.2.1 Experiment instructions

The instruction issued to participants are included in appendix 2.

2.2.1.1 Diapositives

Three diapositives were distributed, numbers 864, 866 and 867 from strip 25 exposed on 5th December 1983 shortly after 0900 GMT. The sun elevation was 15°. The film used was Kodak panchromatic film with an exposure of 1/500 second. Despite exceptional weather conditions for this time of year the conditions were not ideal for photography because of the rather poor illumination and shadowing caused by the low sun angle. Furthermore conditions on this strip were suspect because strip number 25 was the first exposed after the film had jammed in the camera and had to be removed, spliced together and replaced, subsequent operations had to be manually assisted by the crew of the shuttle. These photographs were chosen for the experiment, despite these problems, because they were the best images available which covered an area where suitable control points could be obtained. In addition it was decided that the image quality was not a major consideration in a test of image accuracy (these images were considered to be unsuitable for the test of image content). An additional problem on photograph 866 was the non registration of one of the fiducial marks, this was a disadvantage but did not invalidate the test.

2.2.1.2 Control

The control is fully described in chapter 3.

2.2.1.3 Camera calibration data

The camera calibration certificate provided by Zeiss was supplied to participants, this is included in appendix 3.

2.2.1.4 Shuttle ephemeris data

Participants were supplied with the data issued by NASA regarding the position and attitude of the shuttle at the time of exposure of the photographs to be used. This data was provided as an example of the information which was available and to help participants in determining initial values for the exterior orientation. The initial values computed by the pilot centre were also provided. This information is given in appendix 4.

2.2.2 Participants

A call for participants was issued in June 1984, 23 organisations agreed to take part and were sent the test material, in some cases material was to be passed from one participant to another. 10 centres and the pilot centre actually carried out the test and returned results, these are listed in table 2.3. A full list of names and addresses of participants is given in appendix 1.

Table 2.3 List of participants

Centre No.	Organisation	Instrument	Co-ord system	Exp. No.
11	Norges Geografiske Oppmåling	Wild STK Comparator	Geocentric	11-60G 11-20G
21	Istituto di Topografia, Fotogrammetria e Geofisica	Planicomp C-100	Geocentric	21-60G 21-20G
41	Institut Géographique National, Belgium	Traster 77	Geocentric Lambert	41-60G 41-20G 41-60L 41-20L
51	National Land Survey of Sweden	Planicomp C-100	Geocentric	51-60G 51-20G
72	Landesvermessungsamt Rheinland-Pfalz	Planimat D2		72-60 72-20
73	Bayerisches Landesvermessungsamt	Planicomp C-100	Lambert	73-60L
74	Institut für Angewandte Geodäsie	Planicomp C-100	Geocentric Lambert	74-60G 74-20G 74-60L 74-20L
75	Institut für Photogrammetrie und Topographie, Karlsruhe	DSR11	Geocentric Lambert	75-60G 75-60L
101	Institut Géographique National, France	Traster 1	Geocentric	101-60G 101-20G
111	University College London	DSR1	Geocentric Lambert	111-60G 111-20G 111-60L 111-20L
112	Ordnance Survey	DSR1	Geocentric	112-60G 112-20G

3 Ground Control

3.1 Introduction

The task of identifying and co-ordinating suitable ground control points was undertaken by IGN (France). IGN have compiled a catalogue of 208 control points in the Aix-Marseilles-Avignon area which are suitable for use with images from other sensors in space such as the US large format camera and SPOT. The test area covers the area of stereopair 864-866 of the metric camera and the concept of a European standard test site for satellite data was based on several considerations.

3.2 Preparation of control

The following factors were considered when selecting the test site:

- The size of the test site, 120 x 180 km, which increases the probability of further overlaps with other space data (a Spacelab picture being 9 times larger than a SPOT scene).
- The generally favourable weather conditions encountered in this southern part of France, still increasing the possibility of collecting other space data on this area.
- The large variety of land use and land cover conditions in this stereopair, together with existing elevation differences of up to 1900 m, cultivated valleys and bare mountains, urban areas, large towns and small villages, wide forests and small parcels, shoreline, the river Rhône Delta, dense drainage pattern and dense network of roads and railways.
- The large amount of data available on this area, from previous IGN aerial and field surveys, basic maps and special maps such as that of the permanent inventory of the littoral.

Given these conditions, a useful test area should be available for the future.

The task was conducted by Mr. *P. Naudin*. It took several months to be achieved.

As a result, a catalogue (or inventory) of about 200 points was set up. It consisted of the two following categories of points:

1st category:

About 80 points, easy to identify on the Spacelab black and white pictures, sharp, well contrasted, and well defined, such as cross roads, bridges, or river junctions, and whose three co-ordinates have been measured by transferring the points on to the basic map at 1 : 25,000 scale. Their accuracy depends upon that of the map, and on the permanency of their location (river junctions). It should be within 5 metres.

2nd category:

About 120 points, much more difficult to gather, but more accurate, probably all of their three co-ordinates being known within one metre accuracy, which were chosen among former geodetic and ground control points, previously determined by field surveys for the establishment of the basic map at 1 : 25,000, and whose identification on

the Spacelab pictures turned out to be successful. This long and careful task of detection was stopped once nine areas at the format corners, centres of format sides and at the nadir were supplied with 10 to 12 known points each, which was considered as a sufficient control network.

Both categories of these points can be approximately divided into 8 classes, shown in table 3.1.

Table 3.1 — Classes of points chosen for catalogues

Class of point	Categories				Total	
	No. 1 (from map)		No. 2 (from previous control surveys)			
	Number	%	Number	%	Number	%
Summits	5	6	22	18	27	13
River junctions	20	24	0	0	20	10
Vegetation limits	12	14	4	3	16	8
Line crossings	9	11	13	11	22	10
Bridges	18	21	13	11	31	15
Cross roads	7	8	51	41	58	28
Spots	2	2	10	8	12	6
Corners of cultivated area	12	14	10	8	22	10
Total	85	100	123	100	208	100

As regards the points actually used as control in this OEEPE test, they can be divided into the classes shown in table 3.2.

Their distribution appears very similar to that of the whole 208 points, except that a higher percentage of summits and line crossings has been used, balanced by a lower use of bridges. Among these 62 points, 21 have been used as ground control points and 41 as check points in the OEEPE test of image accuracy.

The type of point which gives the best result is discussed in chapter 7.

Some points are better determined than other; some benefit from merging different features, e. g. a summit is sometimes surmounted by a statue or enhanced by a spot, a line crossing can be also a building or a water tower, a cross road can be outlined by hedges.

One third of the points of the category No. 2 have been established from geodetic measurement and the other two thirds from the establishment of ground control for aerial surveys at 1 : 30,000 scale, including many levelling bench-marks.

Table 3.2 — Classes of points used in OEEPE test

	Cat. No. 1		Cat. No. 2		Total	
Summits	3	12 %	9	26 %	12	20 %
River junctions	6	23 %	0	0 %	6	9 %
Vegetation limits	3	12 %	0	0 %	3	5 %
Line crossings	5	19 %	6	17 %	11	18 %
Bridges	3	12 %	3	8 %	6	10 %
Cross roads	2	7 %	16	43 %	18	29 %
Spots	0	0 %	2	6 %	2	3 %
Corners of cultivated area	4	15 %	0	0 %	4	6 %
Total	26	100 %	36	100 %	62	100 %

In this general inventory, each point has been filed on a one page form depicting:

- a) its origin,
- b) its description,
- c) its location in the map series,
- d) its co-ordinates in various reference grid systems such as:
 - Lambert No. 3, based on the Clarke 1880 ellipsoid;
 - European Datum 1950 (ED 50, coded REG 101 by IGN), based on the Hayford 1909 ellipsoid;
 - NWL 10D modified, known as WGSD, coded REG 602 by IGN, based on WGS 72 ellipsoid;
 - Geocentric system used for SPOT (CIO-BIH or GRS 80). Before being transformed, the NTF Lambert 3 co-ordinates (Nouvelle Triangulation de la France) have been corrected, as regards their elevation, for the difference between the Clarke ellipsoid and the geoid. The corrections are rounded to the nearest metre.
- e) Its portrayal, including:
 - a portion of map at 1 : 50,000 scale;
 - a portion of aerial stereopair at 1 : 60,000 scale, with its reference numbers;
 - a manually drawn sketch at a somewhat larger scale, outlining its location as seen on the previous aerial survey;
 - a portion of enlargements at about 1 : 300,000 or 1 : 400,000 of the relevant area from the Spacelab stereopair.

3.3 Selection and transformation of points

The points to be used for the OEEPE test were selected by the pilot centre from the catalogues supplied by IGN. The model was set up in the Kern DSR1 analytical stereoplotter using as many of the 208 points as could be identified. The points were then classified by the operator according to the ease with which they could be identified and pointed to. A good distribution of the best points were then selected for use in the test.

As indicated in section 3.2 the control was supplied to the pilot centre in two catalogues. The points in the first catalogue were identified and coordinated from 1 : 25,000 map sheets and the co-ordinates were given on the Lambert Conformal projection as used by IGN. The points in the second were given on the Lambert Conformal projection (in metres) and on two datums in latitude and longitude. The co-ordinates of the control points were provided to the participants in two systems, geocentric and Lambert. The Lambert co-ordinates were, for all points, provided directly from the IGN catalogue. In order to provide consistency the geocentric co-ordinates were derived from the Lambert co-ordinates; hence projection co-ordinates were converted to latitude and longitude and then latitude and longitude to geocentric.

Participants were able to choose their own co-ordinate system for restitution and when using the geocentric co-ordinates most worked in a local rectangular system derived by rotating the geocentric co-ordinates with an orthogonal matrix computed from known latitude and longitude in the model; results were then converted back to geocentric for presentation to the pilot centre. Evaluation was done in the geocentric co-ordinates but residuals were rotated to a local rectangular system for realistic presentation; results from the geocentric co-ordinates can then be directly compared to those from the Lambert system.

4 Orientation of Models

4.1 Introduction

The format of metric camera photographs is standard and therefore no special procedures are necessary to set the photographs into interior orientation. Similarly lens distortion correction can be treated normally. However because of the altitude of the photography, special attention needs to be paid to earth curvature and refraction. Relative orientation requires no special methods and beyond a consideration of the co-ordinate system being used, neither does absolute orientation. This chapter gives details of the methods used by the participating centres for inner and relative orientation and also gives the results and conclusions on this part of the test.

4.2 Inner orientation

The methods used for inner orientation and the application of corrections are given in table 4.1.

Table 4.1 — Inner orientation and correction

Test centre	Inner orientation	Lens distortion	Refraction	Comments
11	Affine	yes	no	Refraction 1.8 μm in corner (<i>Schut</i>)
21	Affine	yes	yes	
41	Affine	no	no	
51	Affine	no	no	Analogue method
72	Manual	no	no	
73	Affine	?	no	
74	Affine	yes	no	
101	Similarity	yes	no	
111	Affine	yes	no	
112	Affine	yes	no	

The most serious problem with inner orientation was the very poor registration on photograph 866 of one of the fiducial marks. This was a defect on the original negative and was probably due the malfunctioning of the camera at the time of exposure which was on the first strip exposed since the film jam in the camera and subsequent change of film and manual assistance in film winding from the payload specialists. The poor quality of the fiducial mark itself is not a serious problem but it may be an indication of a more serious problem of film flattening and this topic is returned to later. The corresponding fiducial mark was also poor on photograph 867.

Some centres reported that the point was invisible and accordingly used only three fiducial marks, other were able to observe the point with difficulty.

Most centres used an affine transformation when using analytical plotters, even when only three fiducials were observed, some large residuals were reported with maximum values of up to 80 μm but not enough centres reported residuals from inner orientation for useful conclusions to be drawn. Output from the Zeiss Planicomp gives differential scale change in X and Y and results indicate that some significant changes were present.

— Lens distortion

Lens distortion on the metric camera is small and several centres considered it unnecessary to apply it. Most centres using analytical plotters did apply it using the standard software provided by the manufacturer.

— Conclusions

The photography from the metric camera was not ideal for setting up the inner orientation because of the poor quality of one of the fiducial marks. However most centres set up the photographs satisfactorily and also applied the necessary corrections.

4.3 Refraction

The effect of atmospheric refraction on aerial photography has been investigated in depth by several authors, particularly *Bertram*, *Saastamoinen* and *Schut*. The effects of refraction on an image can be corrected given a reasonable model of the atmosphere. Practical experience has generally been limited to altitudes of less than 10 km.

The effects of refraction across camera windows has also been studied, for example by *Meier* (1974) and *Worton* (1977), but since camera windows are not in common use and it is difficult to collect data concerning pressure and temperature under flight conditions this aspect is frequently not considered.

The tables available for computing the effect of refraction on photographs do not generally give values for altitudes of above 10 km (*Schut* 1969). Since the pressure is very low above this altitude and little refraction takes place it is assumed that the angular error at the camera is negligible. This is borne out by the formula of *Saastamoinen* (1974) for altitudes of over 11 km and by use of the formula for stellar parallax given by *Bomford* (1980). Only one of the experimenters in the test applied a correction for refraction and this amounted to only 1.8 μm in the corner of the image.

As explained by *Meier* (1974) the effect of refraction across a plane parallel glass plate is negligible but if the temperature and pressure on either side of the glass differ then the effect cannot be ignored. *Meier* formulated the problem as follows (extract from *Meier* 1974):

There are in essence two optical factors which affect the geometry of the image (distortion). They are the effect of the pressure difference and the effect of plate flexure.

The change of the glass-air refractive index as a function of the air pressure results, with a sufficiently high accuracy, from the Clausius-Mossotti law as

$$n - 1 = b \cdot p, \quad (2)$$

where

$b = \text{constant},$

$p = \text{pressure},$

and

$n = \text{refractive index}.$

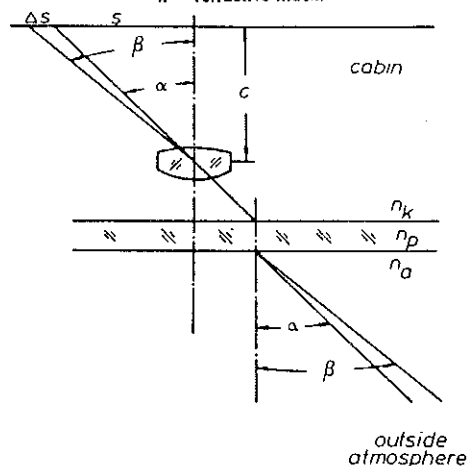


Fig. 4.1

In Fig. 4.1

$c = \text{calibrated focal length},$

$c' = \text{adjusted calibrated focal length},$

$s = \text{image height},$

$\Delta s = \text{distortion},$

$\alpha = \text{angular field},$

$\beta = \text{angular field caused by refraction due to pressure difference},$

$n_k = \text{refractive index of air at } h = 2 \text{ km corresponding to pressure inside cabin}$

and

$n_a = \text{refractive index of air at } h \text{ km altitude}.$

Then

$$\left. \begin{aligned} \Delta s &= (q - 1)s + \left(\frac{q^2 - q}{2c^2} \right) s^3, \\ q &= \frac{n_k}{n_a} = \frac{1 + k}{1 + a}. \end{aligned} \right\} \quad (3)$$

Figure 4.1 — Extract from Meier (1974)

Saastamoinen (1974) shows that if the angular refraction is given as:

$$\alpha = R \tan \beta$$

where R is a function of the density structure of the atmosphere and of the flying altitude then at an angle of 45° from the vertical the effect on the refraction is $\Delta R = n_H - n_A$ where n_H is the refractive index of the actual atmosphere and n_A the refractive index of the air inside the module. Saastamoinen shows that at 6000 m the effect of refraction across the window can be $62 \mu\text{rad}$ ($18 \mu\text{m}$ at 45° on a normal angle photograph) and that this will cancel out the effect of atmospheric refraction.

At altitudes above 10 km, where the effect of atmospheric refraction is decreasing, the total effect of refraction across the window is increasing. *Egels, Hottier and Ducloux* (personal communication) have proposed a formula to deal with this as indicated in figure 4.2.

A point M emits a light ray which is curved according to the path $MO_1 O_2 O_3 O_4 \dots$. The higher O_4 , the straighter is the ray.

If the camera was not pressurized and located in O_1, O_2, O_3, O_4 , the refraction error would be angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4$, which increases with the flying height of the aircraft. But for a spacecraft, the value of α decreases with this height and reaches zero at infinit.

If the camera is pressurized, there is a refraction angle when the light ray goes across the window. The ray gets nearer the vertical.

For an aircraft, the resulting refraction error β decreases when the flying height increases and becomes rather negligible for around 4 to 6 km. For a spacecraft, β increases with the flying height till the limit value β_L as shown in figure 4.3.

At a first approximation, it can be stated that α is perhaps something like 5×10^{-5} radian and β ten times more.

So that it appears necessary to introduce a special correction for refraction when stereo-plotting from Spacelab.

If *Meier's* formula is adopted with the following values:

$$q = n_k/n_a = 1.000214/1$$

$$c = 305 \text{ mm}$$

Then for values of s the following table of corrections can be applied:

s (mm)	20	40	60	80	100	120	140
Δs (μm)	4	9	13	18	24	30	36

The effect of this error in a Spacelab metric camera image is an error in x -parallax in the centre of the model after absolute orientation to points in the corners of the model, resulting in an error in height of 50 m. The practical significance of this is discussed in chapter 6.

4.4 Earth curvature

Correction for earth curvature is not necessary when working with geocentric co-ordinates but is necessary if fitting to co-ordinates on a map projection. This procedure was followed by all centres. Centre 75 carried out a series of tests to determine the feasibility of using analogue instruments; their results are reported separately. Centre 72 used an analogue instrument but worked in geocentric co-ordinates.

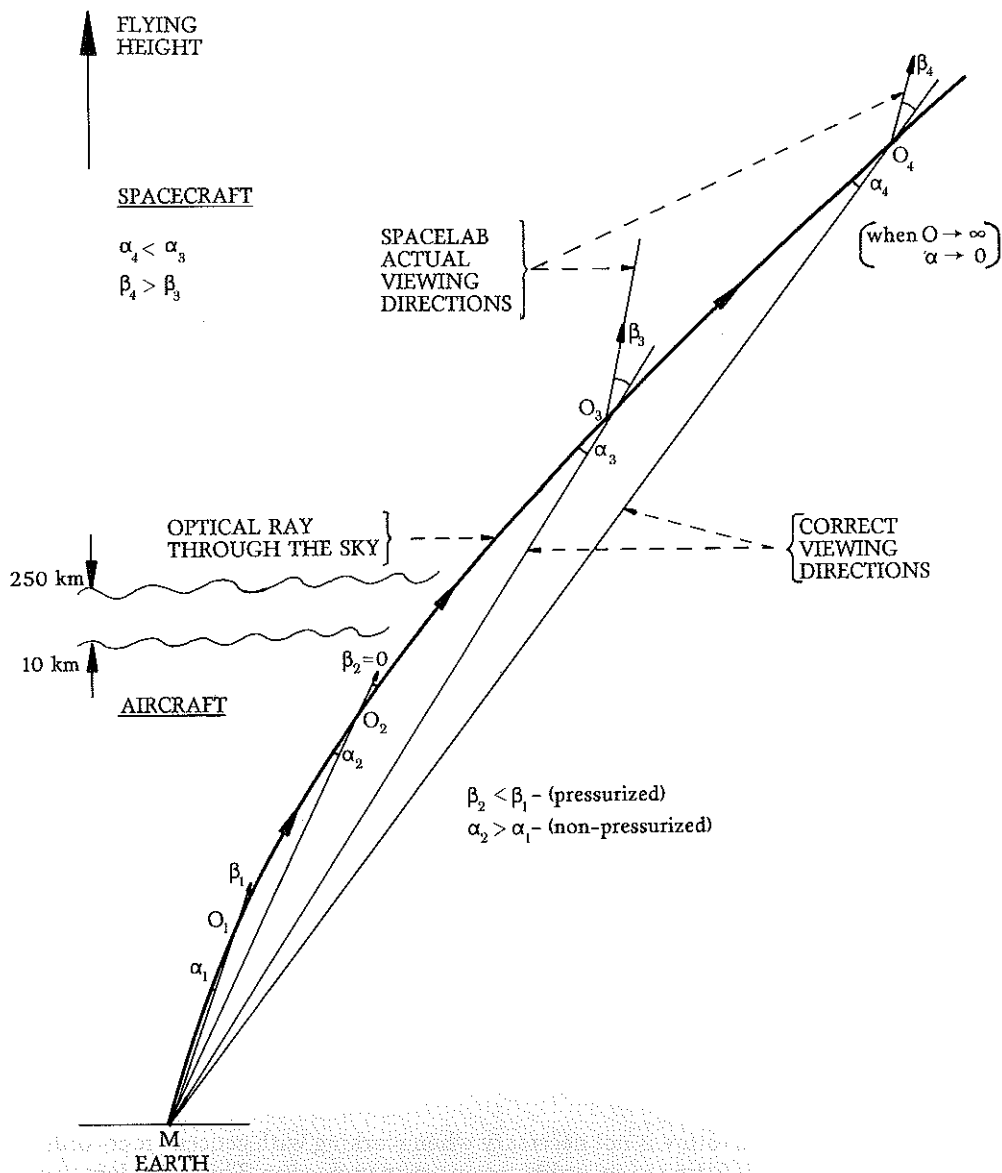


Figure 4.2 — The path of light through the atmosphere and a pressurised module

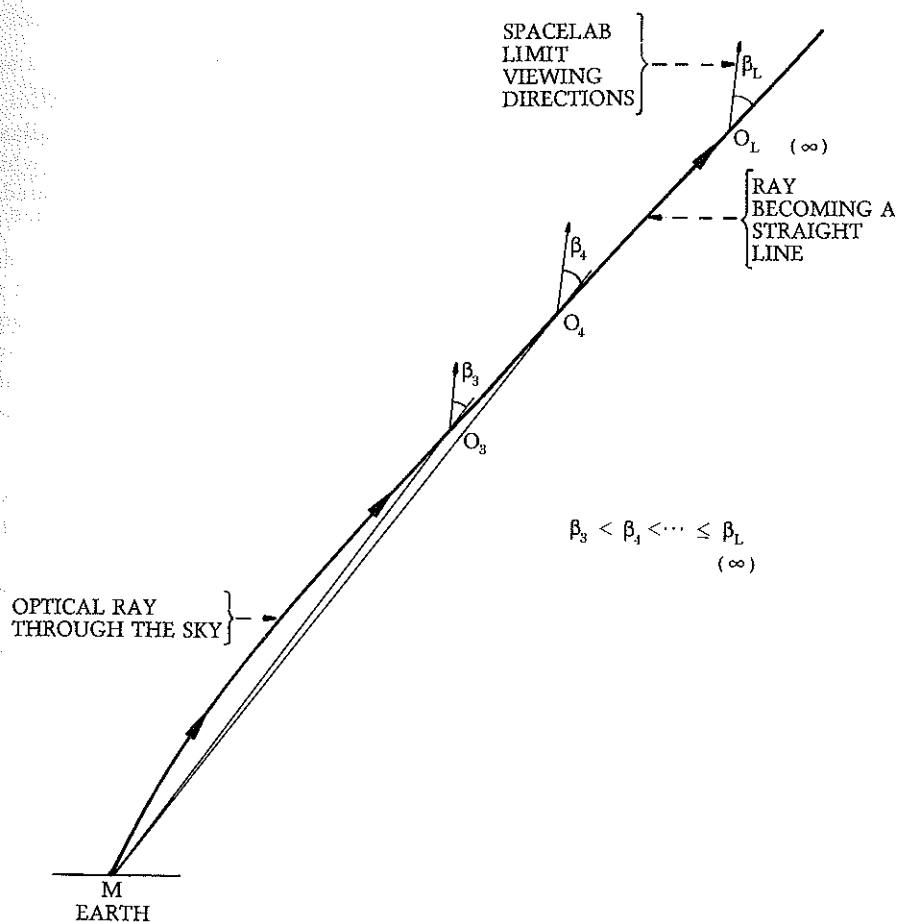


Figure 4.3 — The effect of refraction across a camera window at its maximum

4.5 Relative orientation

Methods used for relative orientation varied, the following methods were reported:

- standard analytical plotter software (Kern, Zeiss);
- combined relative and absolute orientation (bundle method);
- preliminary orientation on instrument followed by computation on computer.

In none of these cases were full details given and in all cases the residual y -parallaxes were within the normally expected tolerances. Hence unless there is an anomaly which could be associated with relative orientation, relative orientation will be considered to be a fixed parameter.

5 Absolute Orientation

5.1 Co-ordinate systems

Two sets of co-ordinates were provided to experimenters as described in chapter 3; one set was given in the Lambert Conformal projection system and the other in geocentric co-ordinates. Several centres carried out the work with both sets of co-ordinates, using earth curvature compensation when using Lambert, but not with the geocentric. Comparisons between the two sets are made in section 5.3. Several centres which used geocentric co-ordinates first transformed these into a local system oriented with the Z axis approximately aligned with the local vertical. Centres were not asked to give details of how this transformation was carried out, only to provide final check co-ordinates in the original system. Assuming that a rigorous three dimensional orthogonal transformation was used for the forward and back transformation there should be no effect on the results.

Centres which reported using local rectangular co-ordinates for the exterior orientation were: 21, 51, 74, 111.

Residuals at the ground control points would initially be produced in the system used for orientation, in the case of using geocentric co-ordinates this would mean that the residuals were not quoted in the conventional X, Y, H system. The system used for quoting residuals is noted.

5.2 Absolute orientation

The absolute orientation of the models from the metric camera used in space is a critical part of the restitution procedure. A number of variables are involved, each of which can have significant effects on the final result. In considering the absolute orientation the following factors relating to photography from space should be remembered:

- The scale of the image is 1 : 820,000 and hence 1 μ m on the image is 0.8 m on the ground, thus σ_0 would be expected to be about 3 m in good conditions of point identification and pointing.
- The camera angle of view is 56°.

- No image motion compensation is applied, image blur is of the order of 15 m on these photographs (exposure time 1/500 sec.).
- Control points were selected from maps and from existing triangulation points and hence were not surveyed for this purpose.

The following parameters were variable within the test centres:

- instrument,
- observer,
- method of orientation,
- number of points rejected.

Tables 5.1 to 5.4 indicate the methods used and the results obtained from all the centres for the four different model/co-ordinate possibilities. Geocentric co-ordinates were supplied as rectangular co-ordinates with their origin near to the centre of the earth, several centres chose to convert these to a local rectangular system for the purpose of orientation, others used the original co-ordinates for orientation but converted the residuals to conform to the conventional E, N, Ht system.

Table 5.1 — Results from absolute orientation for model with 60 % overlap using geocentric (or local rectangular LV) co-ordinates

Centre	Method	No. pts.	Root mean square error of residuals (m)				System
			dx	dy	dz	V	
11	Plan height iteration of block PAT-M 43	14	31	30	43	61	LV
21	PAT-M 43	19	27	20			LV
		21			39	51	LV
41	?	18	31	34	25	52	
51	Plan height iteration. Final orientation in another computer	22	29	32	43	61	LV
72	Analogue instrument	17	21	21	23	34	LV
74	Standard Zeiss software	19	20	22	29	41	LV
75	Standard Kern software	13	13		42		**
101	IGN software	22	22	21	15	34	
111	Standard Kern software	21	22	20	24	38	LV
112	Standard Kern software	17	22	20	30	42	

** see section 5.5

Table 5.2 — Results from absolute orientation for model with 20 % overlap using geocentric (or local rectangular LV) co-ordinates

Centre	Method	No. pts.	Root mean square error of residuals (m)				System
			dx	dy	dz	V	
11	Plan height iteration of block PAT-M 43	9	16	28	29	43	LV
21	PAT-M 43	13	18	18	19	31	LV
41	?	11	22	25	20	40	
51	Plan height iteration. Final orientation in another computer	14	29	19	34	34	LV
72	Analogue instrument	11	17	16	17	26	LV
74	Standard Zeiss software	12	20	20	19	34	LV
101	IGN software	13	11	11	19	25	
111	Standard Kern software	14	17	16	27	36	LV
112	Standard Kern software	11	20	22	30	42	

Table 5.3 — Results from absolute orientation for model with 60 % overlap using Lambert co-ordinates

Centre	Method	No. pts.	Root mean square error of residuals (m)			
			dx	dy	dz	V
41	Bundle method	20	27	18	28	61
73	Standard Zeiss software	18	15	16	21	30
74	Standard Zeiss software	19	21	21	22	37
75	Standard Kern software	13	11		25	27
111	Standard Kern software	20	25	21	28	43

Table 5.4 — Results from absolute orientation for model with 20 % overlap using Lambert co-ordinates

Centre	Method	No. pts.	Root mean square error of residuals (m)			
			dx	dy	dz	V
41	Bundle method	12	19	22	13	32
73	Standard Zeiss software	12	8	11	14	20
74	Standard Zeiss software	12	16	22	11	29
111	Standard Kern software	14	22	20	29	42

A number of conclusions can be immediately drawn from these tables:

- The results within each group are generally consistent.
- The accuracy of the height co-ordinate improves when using 20 % overlap.
- The results when using Lambert co-ordinates are better than those when using geo-centric co-ordinates.

These results will now be examined in more detail considering the parameters listed above.

5.3 Variations in results

The variations within the groups shown in tables 5.1 to 5.4 are greater than variations within groups arranged according to different parameters. Thus no useful comments can be made on the type of instrument used or the method of orientation. The following comments can be made:

- There are insufficient tests carried out by instruments other than analytical plotters to draw significant conclusions, however it is worth noting that the result using the stereo-comparator (centre 11) is the worst in the 60G and 60L tests whilst the analogue instruments are about average.
- There is no consistency in results from the different analytical plotting instruments.
- There is no significant difference in results using different methods of orientation.
- This leads to the conclusion that the variations are mainly due to difference in identification and pointing on control points.

Rejection of points

Table 5.5 shows the points which were rejected by the different centres. There is clearly a difference of practice in that some centres observed all 22 points supplied whilst others rejected some points which they considered impossible to identify satisfactorily. It is perhaps significant that most points were rejected by centre 11 which was using a stereo-comparator and therefore did not have the advantage of being driven to points as is possible with analytical plotters.

Table 5.5 — Points rejected during absolute orientation

Point	Centre									
	11	21	41	51	72	73	74	101	111	112
1003										
1016	PH				PH	PH	PH		H	PH
1017										
2012	PH		PH			PH	PH			PH
2015			PH							
2016	PH				PH					PH
3010										
3012			PH							PH
3017										
4001									H	
4016	PH	P			PH					PH
5004									H	
5014		P			PH	PH	PH			
7018										
7024	PH	P	PH		PH	P				
7022										
8004										
8024										
8025	PH									
9014	PH									
9017		H								
9016										
Totals	7	3 P 1 H	4	0	5	3 PH 1 P	3	0	3 H	5

P — Plan H — Height PH — Plan and height

Different co-ordinate systems

Fewer centres used Lambert co-ordinates and hence the conclusions to be drawn are more limited. Centres 41, 74 and 111 used both sets and in two of the cases for the 60 % overlap the results were better with Lambert, in the third case the result was worse, in the case of the 20 % overlap the results were improved in all three cases. One centre used only Lambert co-ordinates and results were better than the average for those centres using geocentric. The improvement between 60 % and 20 % overlap was also more marked.

These results lead to a tentative conclusion that better results can be obtained using projection co-ordinates with an earth curvature compensation than with using geocentric co-ordinates.

Different overlap

The Base: Height ratio for the model with 60 % overlap is 0.3 whilst that for the model with 20 % overlap is 0.6, thus in theory there is a ratio between the height accuracy of the two models of 2. A comparison of results shown in tables 5.1 and 5.2 show a general improvement in height. In the case of centres 101 and 112 which used geocentric co-ordinates there is an improvement in the vector residual for 101 but not for 112.

The factor of improvement varies between 1.2 and 1.9, there seems to be no consistency in the distribution of these results.

The results in plan also show an improvement in all cases. This can be explained by the improved stereoscopic pointing leading to better plan positioning as well as height accuracy.

Distribution of errors

The most surprising result from the absolute orientation was the systematic error present in the heights. Figures 5.1 to 5.10 show the plots of height residuals from centres using geocentric and Lambert co-ordinates. The presence of a dome shaped pattern is evident in all the plots and is of a similar magnitude in all cases. The pattern is not one associated with errors in relative orientation or due to lens distortion.

The error is consistent with refraction due to pressure change across the camera window as discussed in section 4.3. In order to test this possibility further tests were carried out at the pilot centre.

The corrections set out in section 4.3 were added to the lens distortion correction in the camera file of the DSR1 and the model was set up again to ground control in the geocentric system and the Lambert system. The new residuals in height, together with the original residuals are shown in table 5.6.

The first point to note about these results is the variation in residuals between sets, there is clearly a significant standard deviation of the observations but there is also a trend showing the points in the centre of the model to have lower heights in the corrected sets of co-ordinates. This test is by no means conclusive and more work needs to be carried out into this effect.

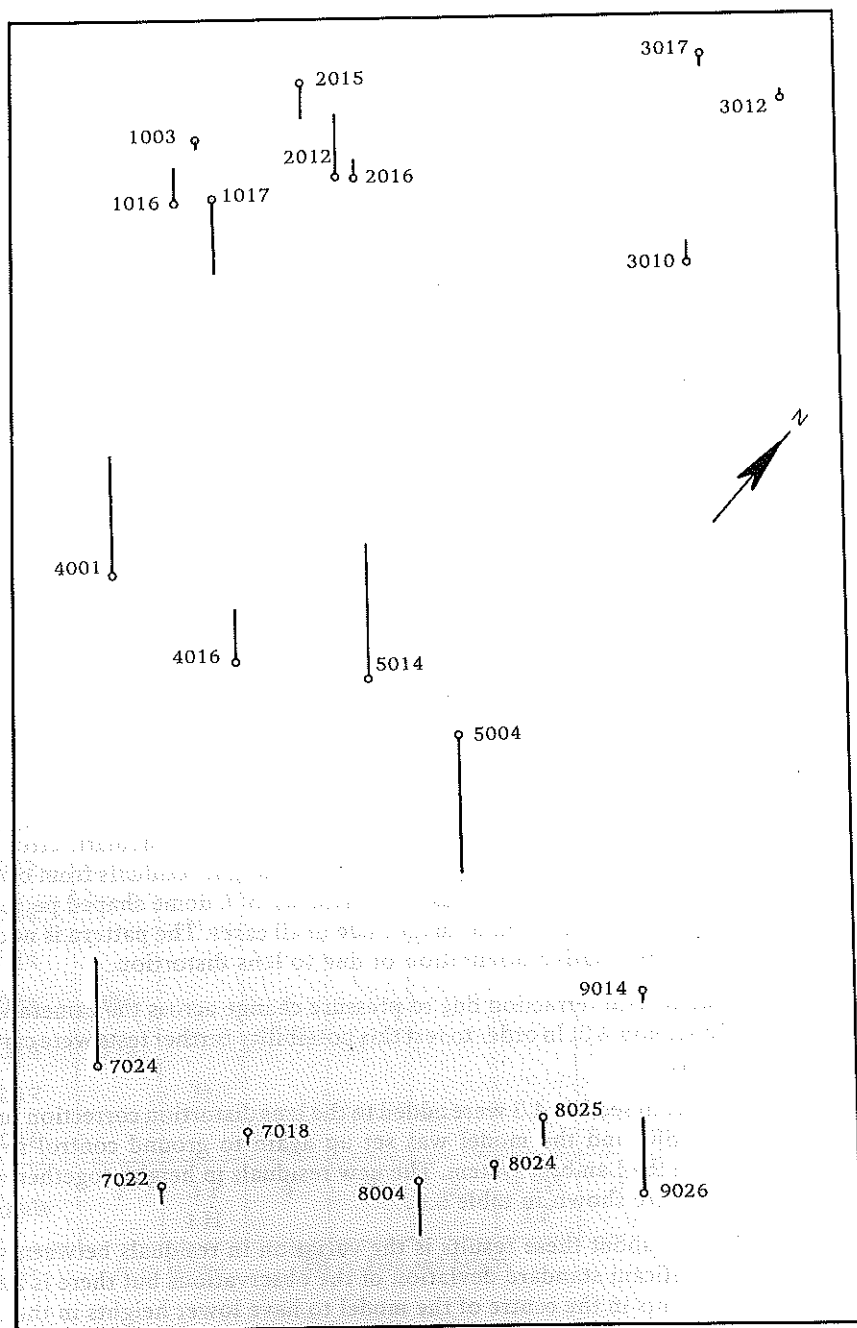


Figure 5.1 — Height residuals from experiment 11-60G
10 mm on vector = 50 m error in height

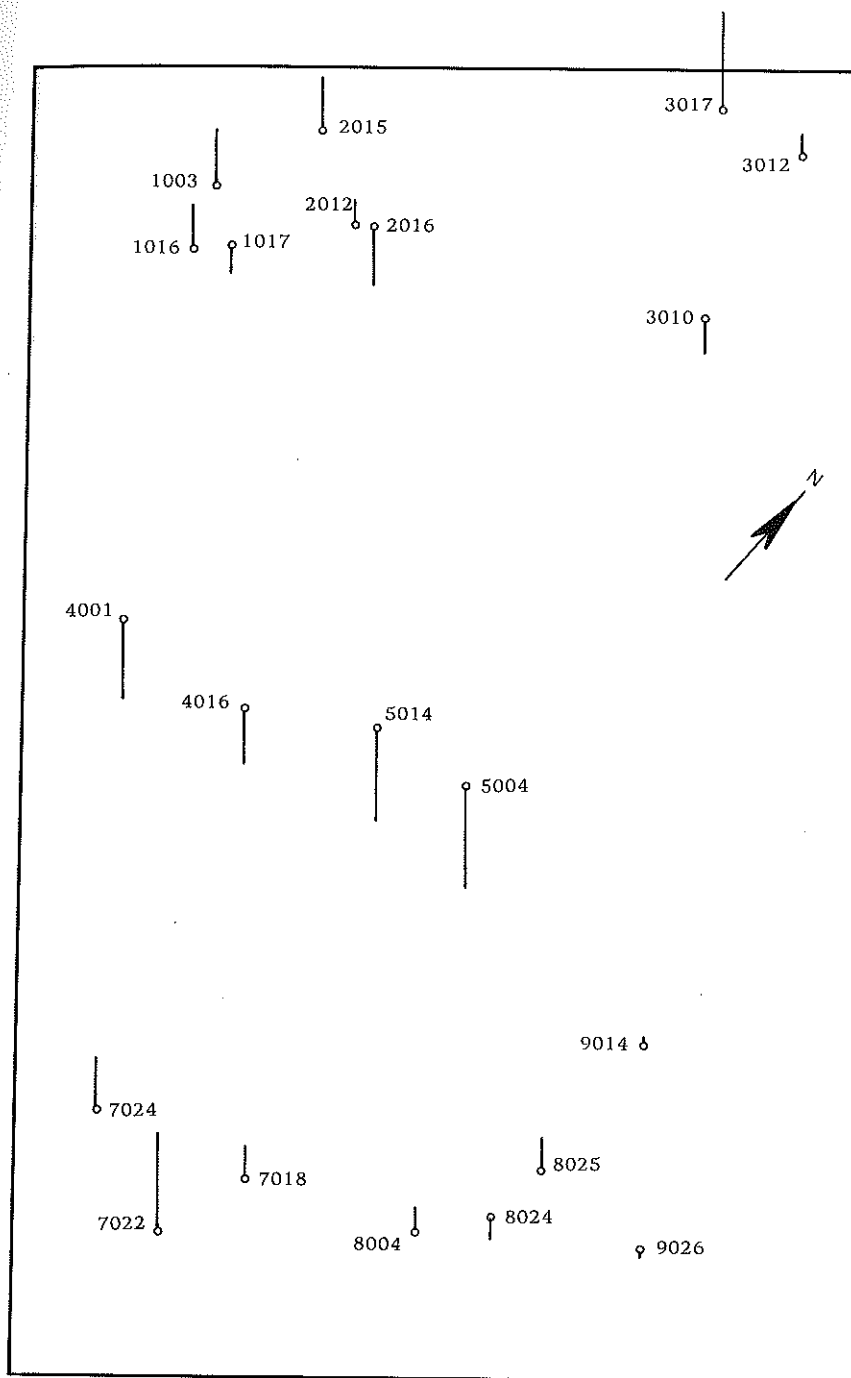


Figure 5.2 — Height residuals from experiment 21-60G
10 mm on vector = 50 m error in height

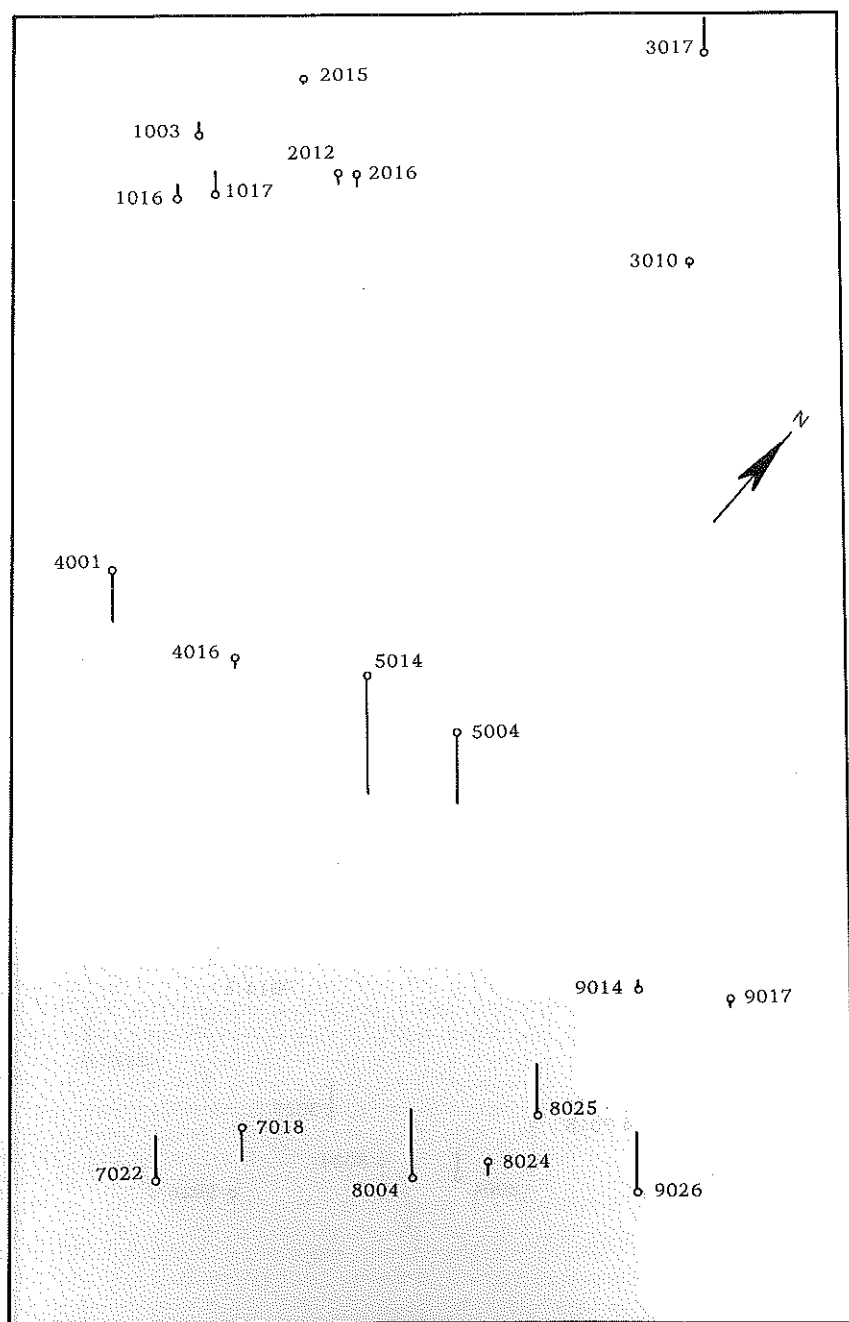


Figure 5.3 — Height residuals from experiment 41-60G
10 mm on vector = 50 m error in height

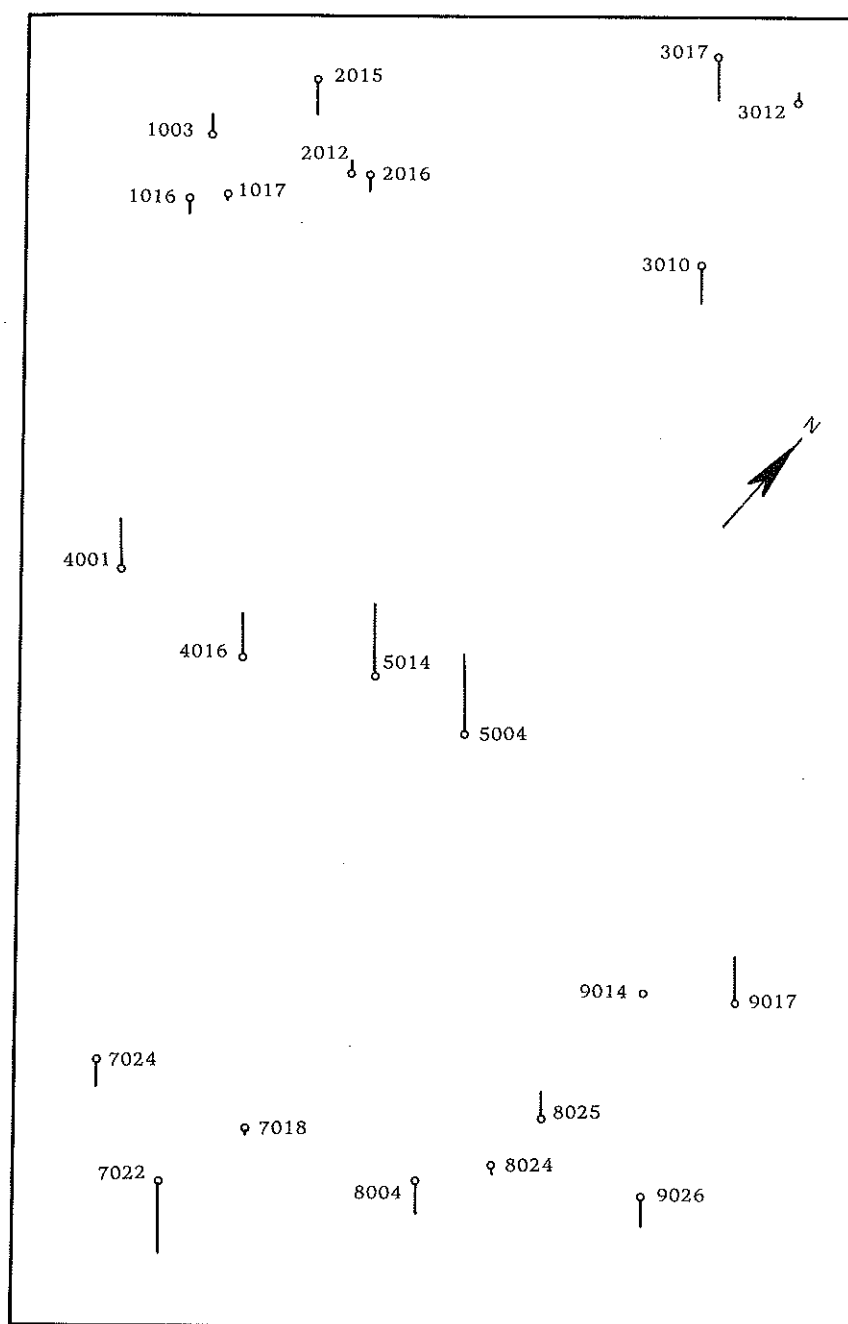


Figure 5.4 — Height residuals from experiment 51-60G
10 mm on vector = 50 m error in height

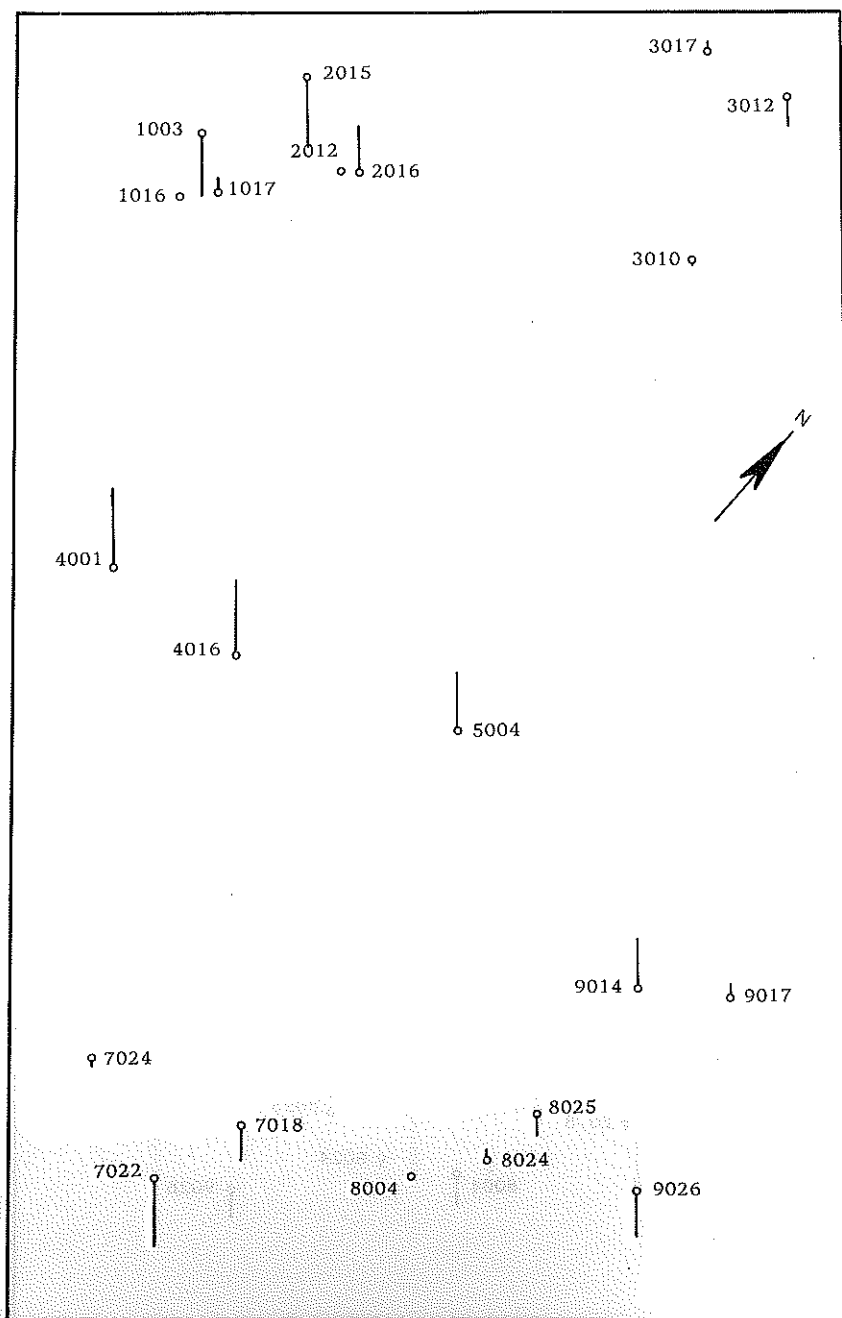


Figure 5.5 — Height residuals from experiment 73-60G
10 mm on vector = 50 m error in height

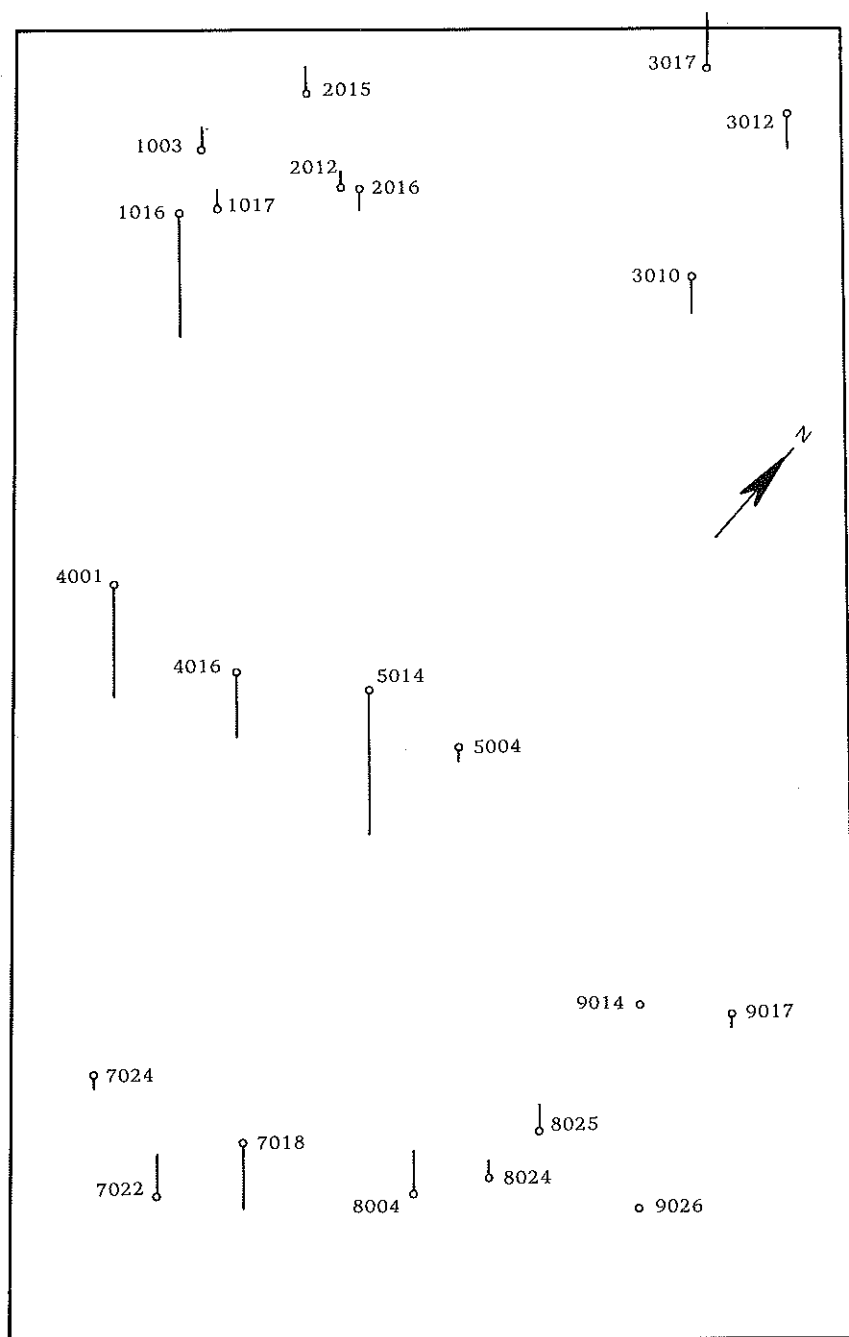


Figure 5.6 — Height residuals from experiment 111-60G
10 mm on vector = 50 m error in height

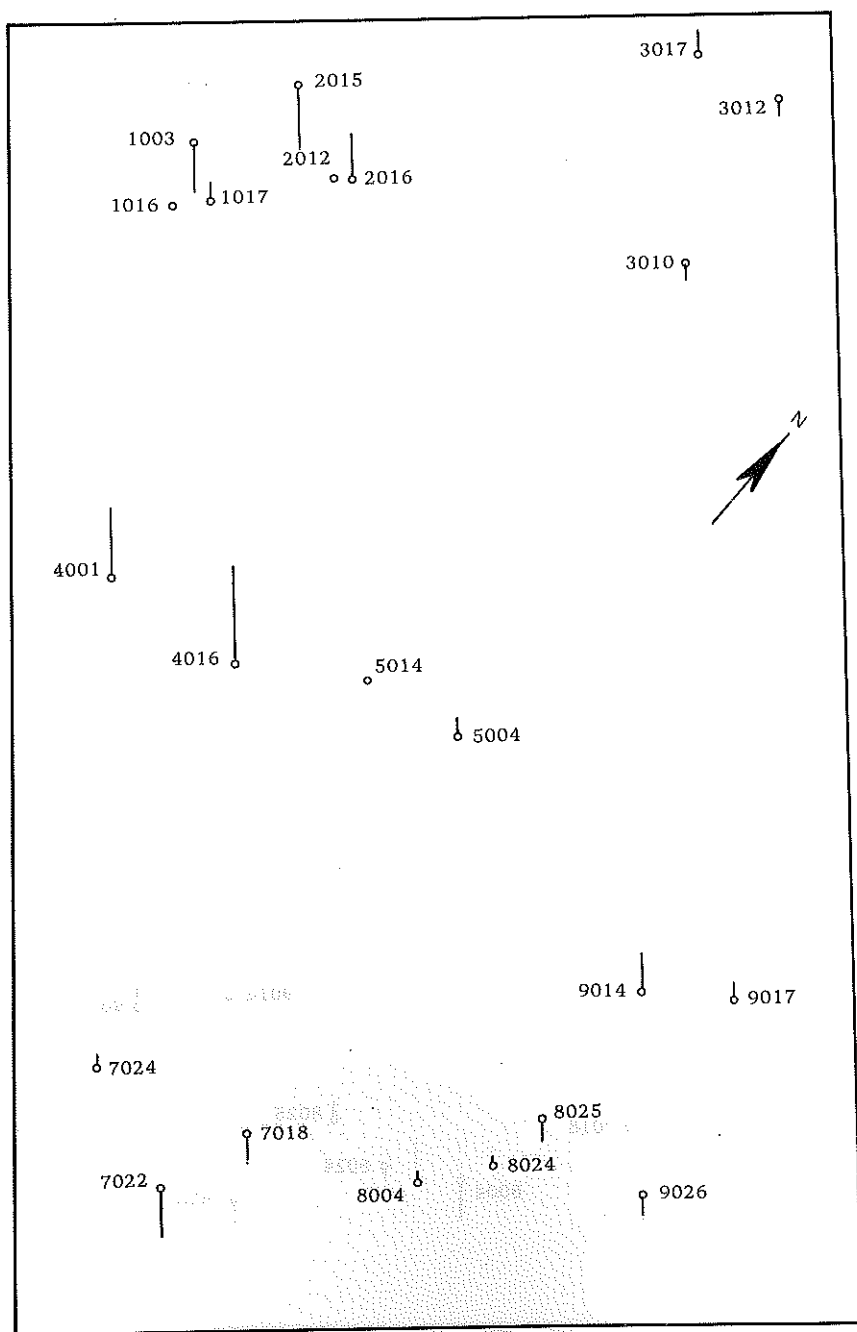


Figure 5.9 — Height residuals from experiment 74-60L
10 mm on vector = 50 m error in height

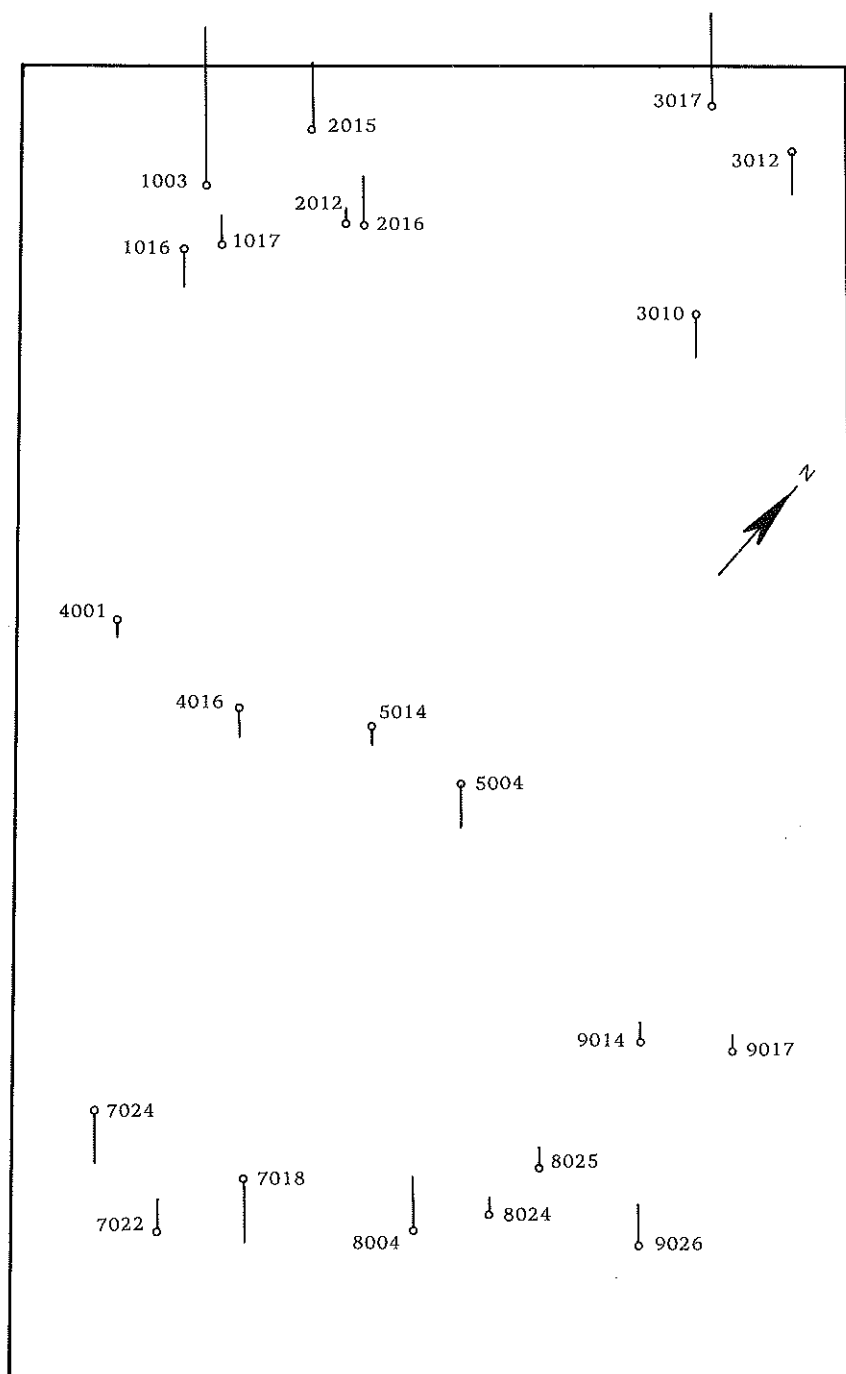


Figure 5.10 — Height residuals from experiment 111-60L
10 mm on vector = 50 m error in height

Table 5.6 — Residuals in Z from absolute orientation after application of correction for refraction

Point	Original geocentric (m)	Original Lambert (m)	Corrected geocentric (m)	Corrected Lambert (m)
7022	32	40	11	28
2015	16	29	51	36
1003	13	12	29	37
3010	-23	-111	-85	-42
4001	-69	-32	-31	-45
5004	-8	-93	-120	-98
8004	31	12	10	9
1016	-78	-17	-24	-13
1017	7	35	36	34
2012	7	20	-2	-14
2016	-14	-38	-13	-17
3012	-19	-36	-40	25
3017	36	45	2	93
4016	-41	-50	-64	-66
5014	-97	-64	-44	-55
7018	-42	-7	-25	-14
7024	-9	-6	-17	2
8024	8	23	25	13
8025	18	-31	1	-20
9014	-1	-19	28	5
9017	-9	-14	-10	-8
9026	0	35	15	38

5.4 Elements of exterior orientation

Centres were asked to provide the elements of exterior orientation which were obtained by their orientation procedure. The values for the rotational elements could not be sensibly analysed because of the use of different instrument and different local co-ordinate systems. However the values for the position of the perspective centre could be used and those provided for the 60G test are given in table 5.7.

Table 5.7 — Co-ordinates of the perspective centres for the 60 % model in geocentric co-ordinates (m)

Centre	Left camera			Right camera			Base		
	X	Y	Z	X	Y	Z	X	Y	Z
41	4773125	403315	4558102	4733945	453333	459529	39180	-50018	-35427
51	243	3083	7877	4077	3234	387	166	150	512
101	348	3096	7754	4158	3146	318	190	050	565
111	314	2841	7902	4193	2968	457	121	127	555
112	517	2716	7497	4506	2801	121	013	085	624
Mean	309	3010	7826	4175	3096	362	134	086	536
σ	129	210	199	186	190	140	64	48	65

The standard deviation of the results indicates the precision with which the co-ordinates of the perspective centre can be found. 150 m at a altitude of 250 km subtends an angle of 2' or represents 0.183 mm on the photograph. It can also be seen that the precision of the base components is greater, indicating that the relative orientation is more precise than the absolute orientation. This also indicates that the provision of accurate co-ordinates of the perspective centre from the spacecraft to an accuracy of 150 m should ensure a good absolute orientation.

5.5 Analogue instruments

Centre number 72 used a Zeiss Planimat instrument for the test and centre number 75 used a Kern DSR11 in order to simulate an analogue instrument.

Centre 72 carried out tests 72-60G and 72-20G and fitted the models to the geocentric co-ordinates, rotated to the local vertical, without applying any corrections to the photograph or model. The results are given after rotation back to the geocentric system in tables 5.1 and 5.2 and are equal to the best from any test centre. In order to plot from this instrument a digital mapping system would be required to convert geocentric co-ordinates to projection co-ordinates but the indication is that sufficient accuracy is possible.

Centre 75 wished to investigate the possibility of using a conventional stereoplotter such as might be used in developing countries. It was considered that, without earth curvature correction, mapping might be possible over small areas. Some results with the Zeiss Jena Topocart were described at the Metric Camera Workshop (Bähr 1985), but the work for the OEEPE test was carried out on a Kern DSR11 and tests were made with and without earth curvature correction, on full and on partial models. The results are given in table 5.8.

Table 5.8 — Results of tests carried out at centre 75 using a Kern DSR11 to simulate an analogue instrument

Test	No. of pts.	Root mean square errors (m)	
		Plan	Height
60G lower part earth curvature correction	7	40.8	27.2
60G upper part earth curvature correction	8	48.3	49.9
60G whole model earth curvature correction	13	8.6	25.7
60G whole model no earth curvature correction	13	12.5	41.6
60L whole model earth curvature correction	13	11.5	25.9
60L whole model no earth curvature correction	13	14.7	186.1

It can be seen that in all cases the use of an earth curvature correction improves the results in height, it is interesting that the use of earth curvature improves the results even when geocentric co-ordinates are used. The use of part models however does not improve the result.

6 Accuracy of Check Points

6.1 Requirements

Centres were provided with descriptions of 43 control points and asked to identify and observe these points and to produce co-ordinates in either the Lambert or geocentric system. Centres were also asked to rate the ease of identification and pointing to the check points.

In this chapter the accuracy results are considered, taking each of the four co-ordinate system/overlap variations in turn and then making some comparisons.

6.2 Method of assessment

The co-ordinates provided by the centres were compared with the ground control and a list of residuals produced. The initial comparison usually showed a number of gross errors, these may have been due to misidentification or other causes. In order to make a comparison between centres, any point with a vector residual of over 100 m in was rejected. The value of 100 m was chosen for all sets and is approximately the 3σ level. A root mean square error in X, Y and Z was computed for each set. All residuals are presented in a local rectangular system so that the Z co-ordinate corresponds to height above sea level. The co-ordinates for each point from all the centres were summed and a mean produced; a root mean square error was calculated for this mean set of co-ordinates.

An initial study of the results from centres using the geocentric co-ordinates showed 9 points with gross errors which were apparent on results from all centres. These 9 points were eliminated from the analysis.

All observed co-ordinates are listed in appendix 6, points listed with zero co-ordinates indicate that the point was not observed by that centre. The residuals calculated from the unedited observations are listed in appendix 7; these results include the gross errors and no root mean square error is shown because of this. The data was edited, points with vector errors of greater than 100 m removed, and root mean square errors calculated for each set of co-ordinates from each centre, these are given in the following sections. As the residuals from these edited observations were computed the mean co-ordinates from the centres were computed and used to compute residuals and root mean square errors which are also shown in the following sections. The number of times which each point was observed is given, providing an indication of the ease of identification of the point.

6.3 Geocentric co-ordinates from 60 % overlap

Tables A71–A77 in appendix 7 show the residuals for 7 sets of data provided in this system. Table 6.1 summarises the results and table 6.2 shows the residuals from the mean co-ordinates.

Two facts stand out clearly from the results: The residuals are higher than those obtained from absolute orientation and more points have been rejected. Five of the centres were using analytical plotters, one an analogue instrument and one a stereo-comparator. The stereo-comparator results are the worst and there is little difference between the results from the analytical plotters. The number of points rejected by the centres varies between 17 and 7 (39 % to 16 %), the best result is that when the most points were rejected.

An inspection of the pattern of residuals does not allow clear conclusions. There appears to be a preponderance of positive residuals in the x-direction, characterised by the fact that no point in groups 1 and 7 have any negative residuals from any centre. The positive residuals also exist in height in the centre of the model, reflecting the deformation noted after absolute orientation.

The mean residuals from all 7 sets of observations are shown in table 6.2 and these show a similar pattern to the individual results indicating a consistency amongst observers. Four points were rejected by all centres. There appears to be no other correlation between the number of centres which observed a point and the magnitude of the residual on that point. If the residuals result from random errors in the observations it may be assumed that points with low residuals in this table are those with truly random observation errors which sum to zero when meaned. Such an assumption would lead to the conclusion that the errors are not random but that points are consistently misobserved by all centres indicating consistent errors in identification or pointing.

Table 6.1 — Root mean square errors (m) for 60 % overlap, local rectangular coordinates. Points with residual greater than 100 m rejected

Experiment	DX	DY	DZ	No. pts.
11-60-G	38	24	31	24
21-60-G	27	20	27	24
51-60-G	27	26	31	26
72-60-G	34	22	28	22
74-60-G	27	22	23	21
101-60-G	34	21	28	30
112-60-G	31	23	37	29

Table 6.2 — Residuals of meaned geocentric co-ordinates (m) with 60 % overlap

Point	DX	DY	DZ	Vector	No. pts.	Description
1005	21	-13	-8	26	4	Intersecting lines
1013	49	-1	-23	54	2	Junction
1015	-83	19	-15	87	1	Road end
1022	66	-10	36	76	3	Junction
1024	44	-6	-10	45	6	Junction
2002	33	-2	7	33	6	Confluence
2004	20	-13	36	43	7	Bend in road in wood
2006	-27	-36	-16	48	7	Confluence
2017	3	20	7	21	3	Junction
3001	8	23	-34	42	6	Bridge
3003	-3	-17	-22	28	6	Summit
4006	-30	-34	43	62	6	Embankment
4014	42	-51	63	91	2	Summit
4015	-3	-42	49	65	4	Summit
4022	-60	33	52	86	2	Level crossing
4026	16	-18	42	49	7	Junction
5002	65	-18	53	86	4	Confluence
5010	-9	15	25	31	6	Summit
5023	-2	1	51	51	3	Junction
6017	-3	-6	22	23	7	Summit
7001	37	0	-24	44	7	Pt. on island
7003	49	-3	-29	57	6	Edge in forest
7005	44	9	0	45	7	Canal
7007	45	15	18	50	7	Runway
7015	30	-17	-1	34	7	Junction
7026	63	-19	-24	70	3	Summit
8001	0	-19	-3	19	7	Edge of forest
8002	6	-34	-9	35	7	Edge of forest
8005	40	28	-34	60	7	Edge of forest
8012	-46	1	21	50	6	Edge of forest
9001	6	34	-35	49	5	Edge of forest
9002	-22	-14	-4	26	4	Edge of lake
9003	-12	12	13	21	6	Intersecting lines
9011	30	-6	-31	44	5	Edge of forest
Root mean square errors						
	37	21	30			

6.4 Geocentric co-ordinates from 20 % overlap

A summary of results from centres setting up the model with 20 % overlap in geocentric co-ordinates is shown in table 6.3.

Table 6.3 — Root mean square errors (m) for 20 % overlap, geocentric co-ordinates.
Points with residuals of greater than 100 m rejected

Experiment	DX	DY	DZ	No. pts.
11-20-G	34	34	26	15
21-20-G	25	20	24	16
41-20-G	34	27	26	14
51-20-G	31	32	29	18
72-20-G	34	25	19	11
74-20-G	27	25	32	14
101-20-G	25	19	28	17
112-20-G	25	25	27	18

There is no significant difference between these results and those from the model with 60 % overlap. The theoretically expected improvement due to the more favourable base to height ratio has not materialised. This is almost certainly because the residuals in fact reflect the problems of identification and pointing rather than the geometry and precision of measurement.

The pattern of the residuals is more random because of the removal of the points in groups 1 and 7 but there is still a tendency to a systematic shift in x and the doming effect.

The residuals of the means are shown in table 6.4.

6.5 Lambert co-ordinates from 60 % overlap

The results from the centres which observed the co-ordinates in the Lambert system are shown in tables A716-A718 in appendix 7 and the root mean square errors summarised in table 6.5.

The number of centres observing the check points in the Lambert system is small but in this small sample the results are much the same as in the geocentric system. The pattern of residuals is also similar showing the systematic shift in the x-direction and a positive trend in height in the centre of the model. The same pattern is shown in the residuals of the means shown in table 6.6.

Table 6.4 — Residuals (m) of meaned co-ordinates from geocentric system with 20 % overlap

Point	DX	DY	DZ	Vector	No. pts.
2002	29	-10	0	30	8
2004	31	-18	12	38	8
2006	-17	-46	-14	51	8
2017	-10	61	21	65	3
3001	17	21	-24	36	7
3003	-9	-9	-11	17	8
5002	56	-8	34	66	6
5010	5	13	36	39	8
5023	16	-15	40	46	5
6017	-2	-2	36	36	5
8001	12	-27	-1	30	8
8002	19	-30	4	35	8
8005	54	25	-25	64	8
8012	-22	-6	6	24	5
9001	28	18	-39	52	7
9002	6	-45	-34	56	7
9003	17	4	3	17	7
9011	51	-13	-23	57	7
Root mean square errors					
	27	26	24		

Table 6.5 — Root mean square errors (m) from 60 % overlap, Lambert system. Points with residuals of greater than 100 m rejected

Experiment	DX	DY	DZ	No. pts.
41-60-L	18	20	19	20
73-60-L	33	27	28	34
74-60-L	26	29	32	32

Table 6.6 — Residuals (m) of meaned co-ordinates from Lambert system
with 60 % overlap

Point	DX	DY	DZ	Vector	No. pts.
1005	31	— 1	17	35	3
1013					
1015	— 95	— 16	— 10	97	1
1022	57	57	47	93	2
1024	36	— 2	41	54	2
2002	19	12	— 18	29	2
2004	32	15	24	43	3
2006	15	— 61	6	63	3
2017	— 32	6	28	43	1
3001	8	40	— 28	49	2
3003	— 2	— 5	— 21	21	3
3016					
3018	8	— 5	28	29	2
4006	— 10	— 31	43	54	3
4014	46	— 13	41	63	2
4015	— 21	— 49	21	57	1
4022	— 87	— 15	36	95	1
4026	1	9	53	54	2
5002	35	30	47	66	3
5010	— 28	4	48	56	3
5012					
5013	— 1	4	70	70	2
5023					
6017	7	11	19	22	2
6029					
7001	5	32	12	34	3
7003	33	42	— 12	54	3
7005	14	51	51	73	1
7007	13	40	16	45	3
7009	29	21	19	40	3
7016	28	57	20	67	1
7026	58	41	— 29	76	2
8001	13	— 11	10	20	3
8002	35	— 30	13	48	3
8005	18	46	— 16	52	3
8009	— 18	10	31	37	2
8012	— 21	— 32	32	50	2
9001	— 11	24	— 23	35	3
9002	22	— 42	— 9	48	3
9003	— 10	4	30	32	3
9006	23	6	31	39	1
9011	29	18	24	42	3
9031	20	6	0	21	1
Root mean square errors					
	31	28	29		

6.6 Lambert co-ordinates from 20 % overlap

The results from the model with 20 % overlap observed with Lambert co-ordinates do show an improvement in all three co-ordinates as seen in table 6.7.

Table 6.7 — Root mean square errors (m) for 20 % overlap, Lambert co-ordinates.
Points with residuals of greater than 100 m rejected

Experiment	DX	DY	DZ	No. pts.
41-20-L	18	16	16	13
73-20-L	17	20	17	20
74-20-L	19	22	17	19

There is no obvious reason for this in comparison with the results from the other models. Possibly the operator was familiar with the check points by the time this model was observed.

6.7 Conclusions

The residuals on the check points confirm the results of the absolute orientation and clearly indicate that the major problem with the use of metric camera photography is the identification of control. The residuals are consistently larger than theory would indicate and the number of gross errors greater than would normally be expected. Many operators have commented on the difficulty of identifying control points.

The accuracy obtained is consistent but less than theoretically predicted and reflects the problems of control point identification.

Table 6.8 — Residuals (m) of meaned co-ordinates from Lambert co-ordinates
with 20 % overlap

Point	DX	DY	DZ	Vector	No. pts.
1005					
1013					
1015					
1022					
1024					
2002	29	5	5	30	3
2004	47	12	13	50	3
2006	23	- 55	1	59	3
2017	- 32	6	18	37	1
3001	2	38	- 8	39	2
3003	- 8	- 28	13	32	3
3016					
3018	27	6	- 3	27	2
4006					
4014					
4015					
4022					
4026					
5002	53	33	41	74	2
5010	- 3	9	44	45	3
5012					
5013	13	4	46	47	2
5023					
6017	0	20	35	40	1
6029					
7001					
7003					
7005					
7007					
7009					
7016					
7026					
8001	12	- 5	18	22	3
8002	24	- 29	13	40	3
8005	31	61	- 2	69	3
8009	4	18	19	26	2
8012	- 21	- 12	30	38	2
9001	5	32	- 12	35	3
9002	35	- 29	- 25	52	3
9003	11	14	15	23	3
9006	25	22	31	45	1
9011	28	20	16	38	3
9031	36	17	0	40	1
root mean square errors					
	18	19	17		

7 Identification of Points

7.1 Introduction

Experience of selection of control points from space imagery has previously been based either on Landsat images or lunar images. Except for a limited use of Skylab photography there has been no need to accurately identify points on photography of the surface of the earth; it is therefore important that some experience be gained in this type of work. Chapter 3 includes some comments from IGN (France) on the selection of points, this chapter deals with the identification of points in the stereo models and their use for control.

Comments in the chapter are given for the points used for absolute orientation and the check points separately. This is because the centres using analytical plotters would have been able to drive to the points with known co-ordinates and hence had the advantage of a good initial position.

The ratings given by the centres have been translated to numerical scores to make analysis easier. Points rated good for identification have been given a score of 3, normal points given 2, poor 1 and unidentified points 0. Some centres did not rate points for identification and for pointing and the ratings for those that did are similar, therefore only one rating has been used, usually that for identification.

7.2 Absolute orientation

7.2.1 Type of point

22 co-ordinated points were supplied for the absolute orientation. The points can be classified according to their type and these are indicated in tables 7.1 and 7.2.

7.2.2 Rejected points

The least acceptable points were those in the category of "others", the worst points, rejected by all centres who rejected points, were the points on a ridge or col with only indistinct detail for identification. The second largest group rejected were the road junctions. This reflects the poor definition of roads on the metric camera imagery, those points rejected were those where little contrast exists between the road and the surrounding area.

7.2.3 Identification of points

A score for each point was determined by summing the ratings given by each centre, each point was then classified and the final score obtained by summing the score for all the points of a particular classification and dividing by the number of point in that classification. The results of the classification is given in table 7.1.

8 Conclusions

The OEEPE test of accuracy of metric camera images has demonstrated the accuracy which can be obtained from a particular set of photographic images from space. It was apparent from the time the mission date was fixed that the metric camera experiment on Spacelab was not going to produce photographs which were ideal for photogrammetric purposes because of the time of year. The final coverage obtained, with very few images over Europe, and the camera failure during the mission, further restricted the universal value of any tests carried out. Nevertheless the mission was a success in demonstrating that high quality images could be obtained from space; the OEEPE test is a success in demonstrating that consistent accuracy can be obtained and in identifying a number of problems which must be dealt with in future missions and mapping projects.

The overall conclusions are summarised as follows:

General

- metric camera data can be set up successfully with analytical or analogue instruments;
- the identification of, and pointing to control points is a significant factor in the accuracy obtained.

Accuracy of control points and check points after absolute orientation

- the accuracy in plan and height can be in the region of 20–30 m;
- the results using Lambert Conformal co-ordinates are better than those using geocentric co-ordinates;
- the accuracy of height improves when using 20 % overlap;
- the effect of the atmosphere and spacecraft environment causes systematic errors in the form of a dome shaped distortion.

Type of control point

- control points related to water and vegetation were rated by operators as being the best but points on summits had the smallest residuals.

Comparison with other tests

- the results are generally consistent with work carried out by individual workers on this and other areas although better results have been obtained when better control is available.

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Appendices

1. List of Participants
2. Experiment Instructions
3. Calibration Certificate
4. Ephemeris
5. Check Point Observations
6. Observations to Check Points
7. Residuals on Check Points

Appendix 1

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Experiment instructions

OEEPE TEST OF SPACELAB METRIC CAMERA PHOTOGRAPHY

Test of Image Accuracy

Materials

Please find enclosed the following materials:

1. Three diapositive images no.s 864, 866, 867 covering an area of SE France.
2. Co-ordinates in Lambert conformal and geocentric systems and location diagrams of ground control points.
3. Camera calibration certificate.
4. Shuttle ephemeris at time of exposure.

Instructions

1. Set up model 864-866 in absolute orientation using the ground control points provided. Record the instrument used, method used and other information requested on the sheet provided.
2. Record ground co-ordinates of the check points in the format described in note C.
3. Repeat 1 and 2 for model 864-867 using and recording only those control points and check points falling on the stereo overlap.

NOTES

All co-ordinate data should be provided as hard copy listings, clearly labelled to indicate the type of data, the method of determination and the test centre.

Note A Plate co-ordinates

Provision of plate co-ordinates is optional. Listings will be acceptable in any format provided that the format is clearly indicated and all points are clearly numbered. If possible the origin of the co-ordinate system should be at the principal point with orientation corresponding to that on the calibration sheet for the fiducial marks.

Note B Ground control points

List the co-ordinates of ground control points as determined by your centre in geocentric co-ordinates and/or projection co-ordinates giving the following information:

- (i) Point number
- (ii) X (Easting) co-ordinate
- (iii) Y (Northing) co-ordinate
- (iv) Z (Height) co-ordinate
- (v) (vi) (vii) Residuals dX , dY , dZ computed from given ground control values X' Y' $dX = X - X'$ (computed - given)

(viii) Assessment of quality of mark for identification and pointing:

GI Good	}	identification
NI Normal		
PI Poor		
II Impossible		
GP Good	}	pointing
NP Normal		
PP Poor		

Note C Check points

List the co-ordinates of check points in the same way as indicated in note B except that residuals will not be included.

OEEPE TEST OF SPACELAB METRIC CAMERA PHOTOGRAPHY

Test of image accuracy

RESULTS SUMMARY SHEET

Name of institution.....

Address

CENTRE NO.

Telephone

Contact

Model number

Instrument used

1. Inner orientation

Method of fit to fiducial marks.....

Standard error of fit left photo no.....right photo no.....

Method of correcting lens distortion.....

Other corrections applied.....

Comments.....

If possible please append a list of plate co-ordinates of all observations
as requested in note A.

2. Relative orientation

Method used

Accuracy of fit y parallaxNo. of points.....

Comments

.....

3. Absolute orientation

Co-ordinate system used Geocentric/UTM (delete one)

Method (Empirical, 3D analytical, plan-height iteration)

.....

Result

No. of plan points.....

rmse x.....rmse y.....rmse vector.....

Comments

.....

Append a plot of residuals scale 1:500 000 with residuals at 1:10 000 scale and a list of accepted values of control points in format described in note B.

4. Record the 6 elements of exterior orientation for each camera position:

Co-ordinate system used.....

Left hand camera

ω_1

ϕ_1

κ_1

X_{S1}

Y_{S1}

Z_{S1}

Right hand camera

ω_2

ϕ_2

κ_2

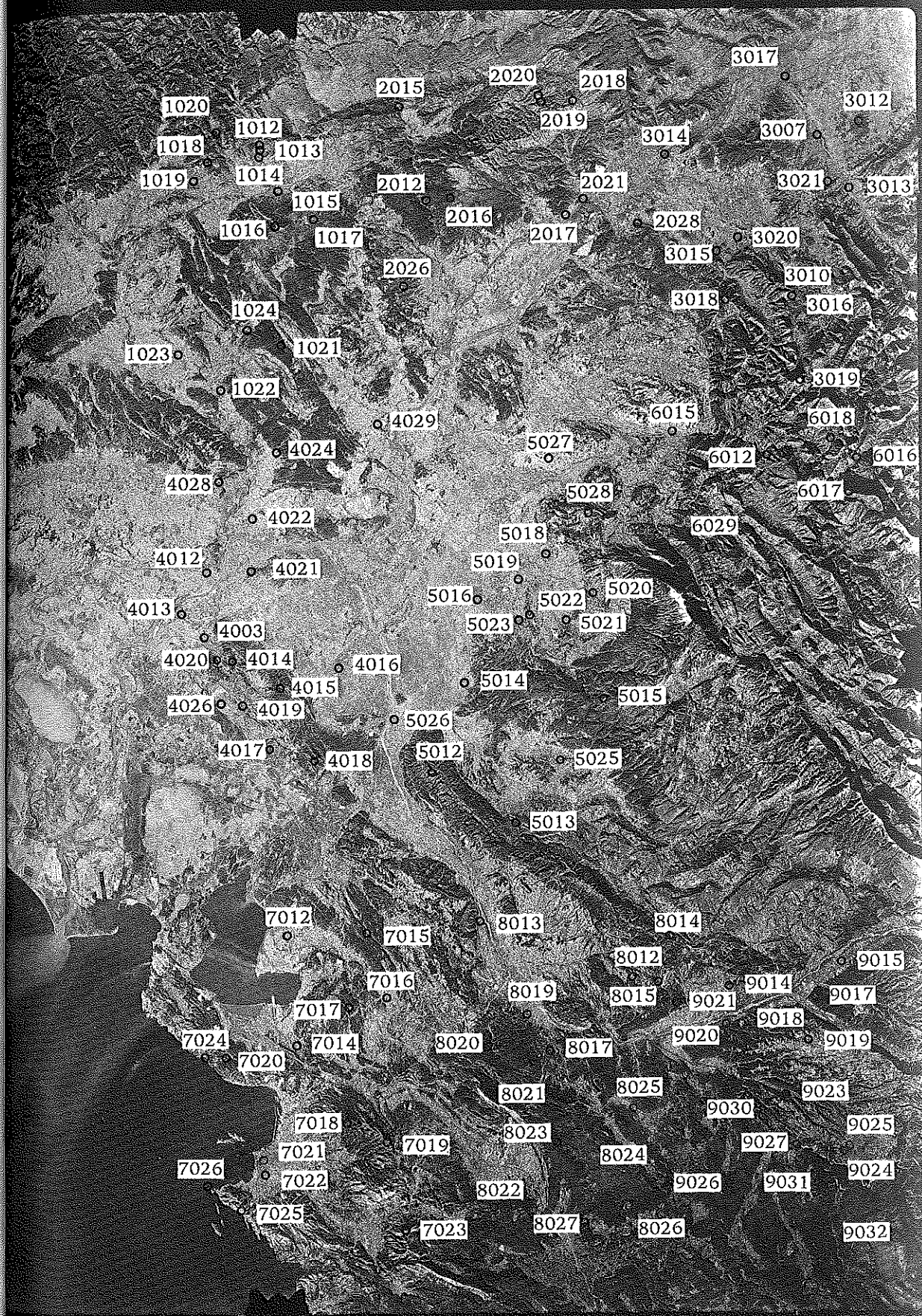
X_{S2}

Y_{S2}

Z_{S2}

5. Co-ordinates of Check Points

Append a list of accepted values for check points as requested in note C.





OEEPE TEST OF ACCURACY OF METRIC CAMERA PHOTOGRAPHY

GROUND CONTROL

GEOCENTRIC CO-ORDINATES

	X(m)	Y(m)	Z(m)
1003	4561705	340358	4429922
1016	4567629	344498	4423843
1017	4564489	347674	4426758
2012	4554293	357499	4436416
2015	4550708	345041	4441151
2016	4553085	359436	4437559
3010	4535233	400245	4453100
3012	4517253	393592	4470964
3017	4519888	381535	4468975
4001	4595532	373978	4392190
4016	4592553	394336	4393564
5004	4581620	423000	4402566
5014	4584243	408750	4400898
7018	4621984	440104	4359332
7024	4627718	419206	4354391
7022	4630881	437085	4349311
8004	4612633	461513	4366363
8024	4606457	467206	4372563
8025	4599894	467730	4379148
9014	4585027	465306	4395174
9017	4579197	474975	4400192
9026	4597711	484764	4379905

LAMBERT CO-ORDINATES

	X(m)	Y(m)	Z(m)
1003	754 038	221 395	123
1016	757 930	212 970	337
1017	761 230	216 980	297
2012	771 465	230 725	308
2015	759 160	236 964	381
2016	773 449	232 335	355
3010	814 947	254 742	971
3012	809 066	280 264	382
3017	796 910	277 345	112
4001	786 262	169 830	15
4016	806 730	172 306	47
5004	835 820	185 563	271
5014	821 474	182 945	69
7018	851 272	125 978	651
7024	830 175	119 025	4
7022	847 925	112 670	11
8004	873 075	136 913	238
8024	879 005	145 500	465
8025	879 800	154 775	316
9014	877 970	176 688	532
9017	887 850	184 063	(Antenna)
9017	887 875	184 070	540 (Summit)
9026	896 915	156 355	537

Appendix 3

This camera has been tested in accordance with the existing regulations. The methods used are based on the Recommended Procedures for Calibrating Photogrammetric Cameras and for Related Optical Tests (International Society of Photogrammetry, 1960, reaffirmed 1964). The optical performance and the external construction are in accordance with our terms of delivery.

1. Calibrated Focal Length

The calibrated focal length is chosen so as to minimize the square sum of the radial measured distortion.

2. Distortion

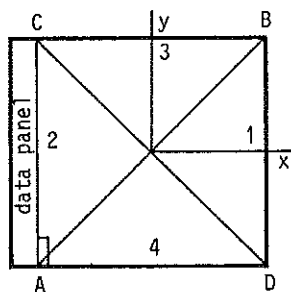
The values of radial distortion refer to the calibrated focal length and to the principal point of symmetry (Section 3). A positive value indicates that the image is further from the centre than its distortionfree position.

The radial distortion is measured for points of the focal plane separated by 10 mm from the axis for each of the four radii A, B, C, and D. AV ist the average radial measured distortion at a given radial distance. Measurements are made at maximum aperture on the goniometer by attaching the filter D (cut-off wavelength 535 nm at transmittance 50 %). The standard deviation of the distortion values given can be assumed to be less than 0.002 mm.

The maximum tangential distortion, i.e. the displacement of the central image from a straight line connecting corresponding image points at equal but opposite angular separations from the axis, does not exceed 0.005 mm.

3. Principal Point and Fiducial Centre

The positions of the principal point of autocollimation and of the fiducial centre (Section 4) are given in a rectangular coordinate system as shown, with the principal point of symmetry as origin.



C A R L Z E I S S
OBERKÖCHEN/WÜRTT.

C A L I B R A T I O N C E R T I F I C A T E
F O R P H O T O G R A M M E T R I C C A M E R A S

CAMERA TYPE: RMK A 30/23 SERIAL NO. 124501
LENS TYPE: TOPAR A1 SERIAL NO. 124516
MAX. APERTURE: F/5.6 NOM. FOCAL LENGTH: 305 MM

1) CALIBRATED FOCAL LENGTH = 305.128 MM

2) DISTORTION /0.001 MM, REFERRING TO P.P. OF SYMMETRY PPS

S/MM= 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

A	0	2	2	1	3	1	-1	1	-2	-2	-2	-2	0	-1	0	1
B	0	-1	0	-2	0	-2	-1	-3	-4	-4	-3	-6	-1	0	4	3
C	0	2	4	2	2	1	3	2	-1	-1	0	0	2	2	2	1
D	0	0	0	-1	-2	-3	-1	-4	-2	-4	-2	-4	2	2	4	6
AV.	0	1	2	0	1	-1	0	-1	-2	-3	-2	-3	1	1	3	3

3) P.P. OF AUTOCOLLIMATION AND FIDUCIAL CENTRE, REFERRING TO PPS

P.P. OF AUTOCOLLIMATION PPA	X=	.042	Y=	.037	MM
FIDUCIAL CENTRE FC	X=	.034	Y=	.045	MM

4) FIDUCIAL MARKS, REFERRING TO PPS

X1=	113.033	X2=	-112.966	X3=	.034	X4=	.035	MM
Y1=	.045	Y2=	.046	Y3=	113.035	Y4=	-112.958	MM
DISTANCES	1-2=	225.999	3-4=	225.993	MM			

5) PHOTOGRAPHIC RESOLVING POWER, IN CYCLES PER MM

AREA WEIGHTED AVERAGE RESOLUTION 39

FIELD ANGLE /DEG = 0 7 14 24

RADIAL LINES	45	44	34	36
TANGENTIAL LINES	45	44	42	37

FILM: AVIPHOT PAN 30 SPEED 21 DIN
DEVELOPED IN ULTRAFIN 1+15

6) FILTERS

KL (CLEAR) NO.	----
B (YELLOW) NO.	124535
D (ORANGE) NO.	124547

7) MAGAZINE PLATEN

EK 24/120 NO. 124831, 127630, 127648

ABTEILUNG FUER GEODÄSIE UND PHOTOGRAMMETRIE

I. A.

R. Schwebel

DATE 11.09.80

Dr.-Ing. R. Schwebel

OEEPE Test of Metric Camera Photography Test of Image Accuracy

Shuttle Ephemeris

The attached sheet Annex A gives the data provided by NASA for the period covered by the exposure of photograph nos. 864, 866 and 867. The exact time of exposure is as follows:

	Date	Time
864	05. 12. 85	9.0.10.552
866		9.0.20.368
867		9.0.25.368

Exterior Orientation

The co-ordinates of the exposure stations have been calculated in geocentric co-ordinates as:

	X(m)	Y(m)	Z(m)
864	4773022	402443	4558014
866	4733725	452917	4593737

and the rotations as:

	ω	ϕ	κ
864	- 32°.979336	34°.678672	213°.35980
866	- 33°.016293	34°.107605	213°.37435

Annex A

STS-9 SPACELAB 1 -METRIC CAMERA- PATH - DATA OF OPERATION 25

STATION NO.	TIME HH:MM:SS.MSS	UNIQUE LAT:DEC	MUS. ALT:AR	VALUITY KPHSC.	ATTITUDE REL. YAW	PITCH	TO UHF ROLL	ATTITUDE REL. YAW	PITCH	TO GREENWICH ROLL
109 2343	9/ 1/ 1:28.0	8.24	284.92	7.505	89.48	89.49	195.19	39.34	-43.74	8.08
109 2344	9/ 1/ 1:29.0	8.27	284.92	7.505	89.51	89.50	195.19	39.34	-43.67	8.13
109 2345	9/ 1/ 1:30.0	8.30	284.92	7.505	89.53	89.52	195.19	39.34	-43.60	8.19
109 2346	9/ 1/ 1:31.0	8.33	284.92	7.505	89.55	89.54	195.19	39.34	-43.53	8.24
109 2347	9/ 1/ 1:32.0	8.36	284.92	7.505	89.57	89.56	195.19	39.34	-43.46	8.30
109 2348	9/ 1/ 1:33.0	8.39	284.92	7.505	89.59	89.58	195.19	39.34	-43.39	8.36
109 2349	9/ 1/ 1:34.0	8.42	284.92	7.505	89.61	89.60	195.19	39.34	-43.32	8.41
109 2350	9/ 1/ 1:35.0	8.45	284.92	7.505	89.63	89.62	195.19	39.34	-43.25	8.46
109 2351	9/ 1/ 1:36.0	8.48	284.92	7.505	89.65	89.64	195.19	39.34	-43.18	8.51
109 2352	9/ 1/ 1:37.0	8.51	284.92	7.505	89.67	89.66	195.19	39.34	-43.11	8.56
109 2353	9/ 1/ 1:38.0	8.54	284.92	7.505	89.69	89.68	195.19	39.34	-43.04	8.61
109 2354	9/ 1/ 1:39.0	8.57	284.92	7.505	89.71	89.70	195.19	39.34	-42.97	8.66
109 2355	9/ 1/ 1:40.0	8.60	284.92	7.505	89.73	89.72	195.19	39.34	-42.90	8.71
109 2356	9/ 1/ 1:41.0	8.63	284.92	7.505	89.75	89.74	195.19	39.34	-42.83	8.76
109 2357	9/ 1/ 1:42.0	8.66	284.92	7.505	89.77	89.76	195.19	39.34	-42.76	8.81
109 2358	9/ 1/ 1:43.0	8.69	284.92	7.505	89.79	89.78	195.19	39.34	-42.69	8.86
109 2359	9/ 1/ 1:44.0	8.72	284.92	7.505	89.81	89.80	195.19	39.34	-42.62	8.91
109 2360	9/ 1/ 1:45.0	8.75	284.92	7.505	89.83	89.82	195.19	39.34	-42.55	8.96
109 2361	9/ 1/ 1:46.0	8.78	284.92	7.505	89.85	89.84	195.19	39.34	-42.48	9.01
109 2362	9/ 1/ 1:47.0	8.81	284.92	7.505	89.87	89.86	195.19	39.34	-42.41	9.06
109 2363	9/ 1/ 1:48.0	8.84	284.92	7.505	89.89	89.88	195.19	39.34	-42.34	9.11
109 2364	9/ 1/ 1:49.0	8.87	284.92	7.505	89.91	89.90	195.19	39.34	-42.27	9.16
109 2365	9/ 1/ 1:50.0	8.90	284.92	7.505	89.93	89.92	195.19	39.34	-42.20	9.21
109 2366	9/ 1/ 1:51.0	8.93	284.92	7.505	89.95	89.94	195.19	39.34	-42.13	9.26
109 2367	9/ 1/ 1:52.0	8.96	284.92	7.505	89.97	89.96	195.19	39.34	-42.06	9.31
109 2368	9/ 1/ 1:53.0	8.99	284.92	7.505	89.99	89.98	195.19	39.34	-41.99	9.36
109 2369	9/ 1/ 1:54.0	9.02	284.92	7.505	90.01	90.00	195.19	39.34	-41.92	9.41
109 2370	9/ 1/ 1:55.0	9.05	284.92	7.505	90.03	90.02	195.19	39.34	-41.85	9.46
109 2371	9/ 1/ 1:56.0	9.08	284.92	7.505	90.05	90.04	195.19	39.34	-41.78	9.51
109 2372	9/ 1/ 1:57.0	9.11	284.92	7.505	90.07	90.06	195.19	39.34	-41.71	9.56
109 2373	9/ 1/ 1:58.0	9.14	284.92	7.505	90.09	90.08	195.19	39.34	-41.64	9.61
109 2374	9/ 1/ 1:59.0	9.17	284.92	7.505	90.11	90.10	195.19	39.34	-41.57	9.66
109 2375	9/ 1/ 2:00.0	9.20	284.92	7.505	90.13	90.12	195.19	39.34	-41.50	9.71
109 2376	9/ 1/ 2:01.0	9.23	284.92	7.505	90.15	90.14	195.19	39.34	-41.43	9.76
109 2377	9/ 1/ 2:02.0	9.26	284.92	7.505	90.17	90.16	195.19	39.34	-41.36	9.81
109 2378	9/ 1/ 2:03.0	9.29	284.92	7.505	90.19	90.18	195.19	39.34	-41.29	9.86
109 2379	9/ 1/ 2:04.0	9.32	284.92	7.505	90.21	90.20	195.19	39.34	-41.22	9.91
109 2380	9/ 1/ 2:05.0	9.35	284.92	7.505	90.23	90.22	195.19	39.34	-41.15	9.96
109 2381	9/ 1/ 2:06.0	9.38	284.92	7.505	90.25	90.24	195.19	39.34	-41.08	10.01
109 2382	9/ 1/ 2:07.0	9.41	284.92	7.505	90.27	90.26	195.19	39.34	-41.01	10.06
109 2383	9/ 1/ 2:08.0	9.44	284.92	7.505	90.29	90.28	195.19	39.34	-40.94	10.11
109 2384	9/ 1/ 2:09.0	9.47	284.92	7.505	90.31	90.30	195.19	39.34	-40.87	10.16
109 2385	9/ 1/ 2:10.0	9.50	284.92	7.505	90.33	90.32	195.19	39.34	-40.80	10.21
109 2386	9/ 1/ 2:11.0	9.53	284.92	7.505	90.35	90.34	195.19	39.34	-40.73	10.26
109 2387	9/ 1/ 2:12.0	9.56	284.92	7.505	90.37	90.36	195.19	39.34	-40.66	10.31
109 2388	9/ 1/ 2:13.0	9.59	284.92	7.505	90.39	90.38	195.19	39.34	-40.59	10.36
109 2389	9/ 1/ 2:14.0	9.62	284.92	7.505	90.41	90.40	195.19	39.34	-40.52	10.41
109 2390	9/ 1/ 2:15.0	9.65	284.92	7.505	90.43	90.42	195.19	39.34	-40.45	10.46
109 2391	9/ 1/ 2:16.0	9.68	284.92	7.505	90.45	90.44	195.19	39.34	-40.38	10.51
109 2392	9/ 1/ 2:17.0	9.71	284.92	7.505	90.47	90.46	195.19	39.34	-40.31	10.56
109 2393	9/ 1/ 2:18.0	9.74	284.92	7.505	90.49	90.48	195.19	39.34	-40.24	10.61
109 2394	9/ 1/ 2:19.0	9.77	284.92	7.505	90.51	90.50	195.19	39.34	-40.17	10.66
109 2395	9/ 1/ 2:20.0	9.80	284.92	7.505	90.53	90.52	195.19	39.34	-40.10	10.71
109 2396	9/ 1/ 2:21.0	9.83	284.92	7.505	90.55	90.54	195.19	39.34	-40.03	10.76
109 2397	9/ 1/ 2:22.0	9.86	284.92	7.505	90.57	90.56	195.19	39.34	-39.96	10.81
109 2398	9/ 1/ 2:23.0	9.89	284.92	7.505	90.59	90.58	195.19	39.34	-39.89	10.86
109 2399	9/ 1/ 2:24.0	9.92	284.92	7.505	90.61	90.60	195.19	39.34	-39.82	10.91
109 2400	9/ 1/ 2:25.0	9.95	284.92	7.505	90.63	90.62	195.19	39.34	-39.75	10.96
109 2401	9/ 1/ 2:26.0	9.98	284.92	7.505	90.65	90.64	195.19	39.34	-39.68	11.01
109 2402	9/ 1/ 2:27.0	10.01	284.92	7.505	90.67	90.66	195.19	39.34	-39.61	11.06
109 2403	9/ 1/ 2:28.0	10.04	284.92	7.505	90.69	90.68	195.19	39.34	-39.54	11.11
109 2404	9/ 1/ 2:29.0	10.07	284.92	7.505	90.71	90.70	195.19	39.34	-39.47	11.16
109 2405	9/ 1/ 2:30.0	10.10	284.92	7.505	90.73	90.72	195.19	39.34	-39.40	11.21
109 2406	9/ 1/ 2:31.0	10.13	284.92	7.505	90.75	90.74	195.19	39.34	-39.33	11.26
109 2407	9/ 1/ 2:32.0	10.16	284.92	7.505	90.77	90.76	195.19	39.34	-39.26	11.31
109 2408	9/ 1/ 2:33.0	10.19	284.92	7.505	90.79	90.78	195.19	39.34	-39.19	11.36
109 2409	9/ 1/ 2:34.0	10.22	284.92	7.505	90.81	90.80	195.19	39.34	-39.12	11.41
109 2410	9/ 1/ 2:35.0	10.25	284.92	7.505	90.83	90.82	195.19	39.34	-39.05	11.46
109 2411	9/ 1/ 2:36.0	10.28	284.92	7.505	90.85	90.84	195.19	39.34	-38.98	11.51
109 2412	9/ 1/ 2:37.0	10.31	284.92	7.505	90.87	90.86	195.19	39.34	-38.91	11.56
109 2413	9/ 1/ 2:38.0	10.34	284.92	7.505	90.89	90.88	195.19	39.34	-38.84	11.61
109 2414	9/ 1/ 2:39.0	10.37	284.92	7.505	90.91	90.90	195.19	39.34	-38.77	11.66
109 2415	9/ 1/ 2:40.0	10.40	284.92	7.505	90.93	90.92	195.19	39.34	-38.70	11.71
109 2416	9/ 1/ 2:41.0	10.43	284.92	7.505	90.95	90.94	195.19	39.34	-38.63	11.76
109 2417	9/ 1/ 2:42.0	10.46	284.92	7.505	90.97	90.96	195.19	39.34	-38.56	11.81
109 2418	9/ 1/ 2:43.0	10.49	284.92	7.505	90.99	90.98	195.19	39.34	-38.49	11.86
109 2419	9/ 1/ 2:44.0	10.52	284.92	7.505	91.01	91.00	195.19	39.34	-38.42	11.91
109 2420	9/ 1/ 2:45.0	10.55	284.92	7.505	91.03	91.02	195.19	39.34	-38.35	11.96
109 2421	9/ 1/ 2:46.0	10.58	284.92	7.505	91.05	91.04	195.19	39.34	-38.28	12.01
109 2422	9/ 1/ 2:47.0	10.61	284.92	7.505	91.07	91.06	195.19	39.34	-38.21	12.06
109 2423	9/ 1/ 2:48.0	10.64	284.92	7.505	91.09	91.08	195.19	39.34	-38.14	12.11
109 2424	9/ 1/ 2:49.0	10.67	284.92	7.505	91.11	91.10	195.19	39.34	-38.07	12.16
109 2425	9/ 1/ 2:50.0	10.70	284.92	7.505	91.13	91.12	195.19	39.34	-38.00	12.21
109 2426	9/ 1/ 2:51.0	10.73	284.92	7.505	91.15	91.14	195.19	39.34	-37.93	12.26
109 2427	9/ 1/ 2:52.0	10.76	284.92	7.505	91.17	91.16	195.19	39.34	-37.86	12.31
109 2428	9/ 1/ 2:53.0	10.79	284.92	7.505	91.19	91.18	195.19	39.34	-37.79	12.36
109 2429	9/ 1/ 2:54.0	10.82	284.92	7.505	91.21	91.20	195.19	39.34	-37.72	12.41
109 2430	9/ 1/ 2:55.0	10.85	284.92	7.505	91.23	91.22	195.19	39.34	-37.65	12.46
109 2431	9/ 1/ 2:56.0	10.88	284.92	7.505	91.25	91.24	195.19	39.34	-37.58	12.51
109 2432	9/ 1/ 2:57.0	10.91	284.92	7.505	91.27	91.26	195.19	39.34	-37.51	12.56
109 2433	9/ 1/ 2:58.0	10.94	284.92	7.505	91.29	91.28	195.19	39.34	-37.44	12.61
109 2434	9/ 1/ 2:59.0	10.97	284.92	7.505	91.31	91.30	195.19	39.34	-37.37	12.66
109 2435	9/ 1/ 3:00.0	11.00	284.92	7.505	91.33	91.32	195.19	39.34	-37.30	12.71
109 2436	9/ 1/ 3:01.0	11.03	284.92	7.505	91.35	91.34	195.19	39.34	-37.23	12.76
109 2437	9/ 1/ 3:02.0	11.06	284.92	7.505	91.37	91.36	195.19	39.34	-37.16	12.81
109 2438	9/ 1/ 3:03.0	11.09	284.92	7.505	91.39	91.38	195.19	39.34	-37.09	12.86
109 2439	9/ 1/ 3:04.0	11.12	284.92	7.505	91.41	91.40	195.19	39.34	-37.02	12.91
109 2440	9/ 1/ 3:05.0	11.15	284.92	7.505	91.43	91.42	195.19	39.34	-36.95	12.96

Appendix 5

Control Values for Check Points in Geocentric System in Metres

1005, 574184, 347765, 416813
 1013, 563339, 335009, 428679
 1015, 564872, 341260, 426590
 1022, 582765, 355403, 407011
 1024, 576825, 351786, 413751
 2002, 548223, 352811, 442696
 2004, 550185, 366772, 439926
 2006, 544213, 355365, 446666
 2017, 545343, 372608, 443938
 3001, 520232, 379563, 468785
 3003, 528200, 401603, 459413
 3016, 534536, 404047, 452972 R
 3018, 540373, 397238, 448358 R
 4006, 592820, 371335, 395239
 4014, 599913, 382868, 387183
 4015, 598067, 390579, 388655
 4022, 588767, 371152, 399447
 4026, 603336, 386588, 382961
 5002, 573302, 398569, 413062
 5010, 575536, 418671, 409386
 5012, 593387, 413833, 391577 R
 5013, 590099, 427291, 393605 R
 5023, 575957, 408049, 409601
 6017, 544152, 428939, 441960
 6029, 551253, 420054, 434149 R
 7001, 631127, 428669, 349868
 7003, 624332, 437208, 356571
 7005, 622669, 418441, 359784

7007, 619473, 421188, 362883
 7009, 625104, 428765, 356221
 7016, 610716, 431700, 371260 R
 7026, 635854, 432275, 344579
 8001, 605188, 445115, 375948
 8002, 601597, 453756, 378748
 8005, 612253, 471083, 365917
 8009, 609371, 455695, 371512 R
 8012, 591522, 454558, 389512
 9001, 594438, 488934, 382779
 9002, 588230, 494226, 388648
 9003, 579947, 484557, 398539
 9006, 579014, 472259, 400387 R
 9011, 587949, 492134, 389381
 9031, 590499, 493781, 385636 R

R POINTS NOT INCLUDED IN ANALYSIS

Appendix 6

Observations to Check Points

The following tables contain the co-ordinates of the check points observed by the participating centres recorded in metres in the geocentric system or the Lambert system.

Zero values indicate that the point was not observed.

All co-ordinates in metres.

11-60-g

1005,574259,347828,416868
1013,563310,335067,428734
1015,564897,341138,426549
1022,582782,355501,407072
1024,576747,351825,413785
2002,548206,352833,442717
2004,550245,366809,439979
2006,544253,355384,446623
2017,545337,372662,443956
3001,520190,379539,468773
3003,0,0,0
3016,534370,405182,453177
3018,540080,397352,448373
4006,592909,371312,395274
4014,599985,382928,387237
4015,598120,390722,388711
4022,588858,371085,399511
4026,603374,386634,382971
5002,573351,398652,413155
5010,575559,418689,409398
5012,593471,413879,391547
5013,590173,427295,393671
5023,576078,408117,409634
6017,544207,428951,441990
6029,557528,420200,427806
7001,631115,428679,349919
7003,624286,437250,356580

7005,622638,418459,359799
7007,619477,421194,362951
7009,625099,428788,356261
7016,610643,431724,371431
7026,635791,432322,344584
8001,605222,445110,375973
8002,601585,453788,378705
8005,612207,471072,365957
8009,609292,455945,371532
8012,591595,454526,389529
9001,594402,488926,382808
9002,588280,494258,388623
9003,579976,484552,398581
9006,579016,472064,400464
9011,587886,492203,389339
9031,591017,493860,386154

21-60-g

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101-60-g

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 8009,867287,143031,1038
 8012,866932,168390,529
 9001,901198,160590,491
 9002,906814,168878,459
 9003,897416,182088,679
 9006,885198,184419,374
 9011,904705,169744,648
 9031,906284,165237,688

41-20-L

2002,767067,239592,90
2004,780958,235854,351
2006,769771,245100,157
2017,0,0,0
3001,794917,277041,87
3003,816606,264107,554
3016,0,0,0
3018,0,0,0
5002,811832,199628,44
5010,831749,194817,424
5012,0,0,0
5013,0,0,0
5023,0,0,0
6017,0,0,0
6029,0,0,0
8001,857009,149427,305
8002,865810,153666,257
8005,882697,136641,334
8009,0,0,0
8012,0,0,0
9001,901237,160613,475
9002,906806,168927,488
9003,897443,182115,674
9006,0,0,0
9011,904706,169760,658
9031,0,0,0

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2002,767055,239789,140
2004,780934,235849,390
2006,769769,245087,209
2017,786900,241930,79
3001,794936,277085,107
3003,816594,264134,504
3016,818657,254976,702
3018,811842,248079,900
5002,811800,199610,71
5010,831726,194830,389
5012,0,0,0
5013,839776,173119,474
5023,821053,194797,188
6017,843242,239738,1397
6029,0,0,0
8001,856964,149445,331
8002,865783,153680,263
8005,882678,136647,355
8009,867400,143076,1031
8012,866947,168386,541
9001,901223,160604,458
9002,906774,168951,442
9003,897428,182098,656
9006,885085,184451,367
9011,904696,169755,654
9031,906270,165230,704

74-20-L

2002,767069,239599,135
2004,780949,235844,384
2006,769778,245099,204
2017,0,0,0
3001,0,0,0
3003,816614,264051,483
3016,0,0,0
3018,811807,248041,890
5002,811795,199605,74
5010,831728,194820,405
5012,826207,169677,532
5013,839779,173108,481
5023,0,0,0
6017,0,0,0
6029,0,0,0
8001,856988,149426,335
8002,865765,153667,293
8005,882683,136657,369
8009,867318,143060,1028
8012,866932,168415,525
9001,901214,160605,483
9002,906814,168899,454
9003,897424,182099,668
9006,885200,184435,374
9011,904706,169755,627
9031,906286,165242,690

Appendix 7

Residuals on Check Points

The following tables contain the residuals calculated by the pilot centre from the values given in appendix 6. All residuals are in metres in either a local rectangular system, (from geocentric co-ordinates), or in Lambert system.

No residuals are shown on a point which was not observed.

No points have been rejected.

Root mean square errors given in tables in the text have been calculated from these values after rejecting points with residuals of greater than 100 m.

Table A7.1

test no. 11-60-g				
ptno	dx	dy	dz	vector
1005	28	-52	93	110
1013	82	0	21	85
1015	-83	19	-15	87
1022	88	-46	61	117
1024	85	24	-30	94
2002	35	3	4	35
2004	19	-25	82	88
2006	-27	-52	-3	59
2017	49	-27	12	57
3001	0	30	-40	50
3003				
3016	970	-638	99	1166
3018	208	91	-196	300
4006	-46	-4	87	98
4014	29	-47	93	108
4015	97	-97	86	162
4022	-64	42	105	130
4026	16	-45	37	61
5002	76	-32	105	134
5010	6	-17	26	32
5012	-28	-86	43	100
5013	-5	-1	99	99
5023	-2	-85	114	143
6017	-7	-17	61	64
6029	-6371	-6254	132	8928
7001	38	25	27	53
7003	58	-5	-24	63
7005	36	9	-11	39
7007	35	30	50	68
7009	38	7	26	46
7016	139	106	67	188
7026	69	-3	-39	79
8001	-9	2	41	43
8002	7	-41	-36	55
8005	37	50	-6	62
8009	224	-135	-26	263
8012	-53	0	62	82
9001	28	37	-6	47
9002	-17	-59	21	64
9003	2	13	50	51
9006	-98	181	42	210
9011	61	-44	-70	102
9031	31	-12	736	737
root mean square errors				
	985	960	131	

Table A7.2

test no. 21-60-g

ptno	dx	dy	dz	vector
1005	22	-8	-22	32
1013				
1015				
1022				
1024	28	-20	-16	38
2002	40	-10	34	54
2004	28	-5	23	36
2006	-28	-31	-15	45
2017				
3001	-18	-7	-38	43
3003	7	19	-46	50
3016				
3018	114	146	-251	312
4006	-29	-69	37	84
4014	19	-48	48	70
4015				
4022				
4026	22	-10	51	57
5002	52	-17	64	84
5010	11	6	28	31
5012				
5013				
5023	32	-329	52	335
6017	-3	-1	25	25
6029	-6381	-6240	119	8926
7001	50	-19	-54	76
7003	-63	-319	-281	430
7005	43	7	-18	47
7007	50	15	31	61
7009	30	-19	-18	39
7016				
7026	68	-18	-72	101
8001	6	-18	-6	20
8002	13	-52	16	56
8005	63	25	-22	72
8009	8	24	13	29
8012	-46	-1	17	49
9001	11	34	-32	48
9002	-25	-20	0	32
9003	-26	23	35	49
9006				
9011	27	-9	-34	45
9031				
root mean square errors				
	974	955	67	

Table A7.3

test no. 51-60-g				
ptno	dx	dy	dz	vector
1005	1914	-837	18	2089
1013				
1015	66	79	13	104
1022	90	49	59	118
1024	47	10	1	48
2002	44	8	4	45
2004	23	-3	29	37
2006	-22	-44	9	50
2017	-34	72	26	84
3001	53	41	-43	79
3003	-1	-12	-30	32
3016	-124	70	42	149
3018	-12232	13131	-1441	18004
4006	-14	-20	55	60
4014	37	-33	68	85
4015	14	-71	64	97
4022	-49	55	75	105
4026	22	0	48	53
5002	103	-8	78	129
5010	13	17	34	40
5012	6	-41	68	80
5013	14	8	71	73
5023	14	7	64	66
6017	0	-5	19	20
6029				
7001	45	-27	-42	66
7003	50	-8	-55	75
7005	42	2	-17	46
7007	45	8	-6	46
7009	33	-28	-19	47
7016				
7026	88	-55	-74	127
8001	3	-4	0	5
8002	10	-43	14	46
8005	16	34	-23	44
8009	209	-108	-26	237
8012	-58	9	43	72
9001	-6	41	-28	50
9002	-23	-73	-54	93
9003	-8	16	-10	21
9006	-60	107	6	123
9011	20	12	-16	28
9031	23	-1	686	686
root mean square errors				
	1889	2007	247	

Table A7.4

test no. 72-60-g

ptno	dx	dy	dz	vector
1005	-6777	-7365	51	10008
1013				
1015				
1022	65	-12	55	86
1024	40	-19	14	46
2002	42	-16	-13	46
2004	55	-17	22	62
2006	-24	-42	-16	51
2017				
3001	67	35	-19	78
3003	0	-13	6	14
3016	-123	69	31	144
3018	379	-83	-196	434
4006	-10	-16	45	49
4014	-300	867	109	924
4015	24	-55	54	81
4022	-45	51	68	96
4026	23	-18	61	68
5002	70	3	39	81
5010	-44	54	61	93
5012				
5013	22	-2	40	45
5023				
6017	2	-14	9	17
6029	-6387	-6230	103	8922
7001	35	14	21	43
7003	48	-2	-9	49
7005	52	6	25	58
7007	58	19	35	71
7009	42	-1	18	45
7016	169	73	31	187
7026	123	-4	-6	123
8001	20	-17	19	32
8002	24	-22	-3	32
8005	47	33	-27	63
8009	74	-20	28	81
8012				
9001				
9002				
9003				
9006				
9011				
9031	44	1	676	677
root mean square errors				
	1423	1477	113	

Table A7.5

test no. 74-60-g

ptno	dx	dy	dz	vector
1005	13	-15	23	30
1013				
1015				
1022	89	18	46	102
1024	34	-16	4	38
2002	-547	169	2	573
2004	21	-11	33	40
2006	-31	-40	-8	52
2017				
3001				
3003	-18	-85	-20	90
3016				
3018	139	125	-197	272
4006	-50	1	61	79
4014	29	-50	103	118
4015	-49	-18	47	70
4022	-63	43	85	114
4026	16	-8	70	72
5002	71	-17	79	108
5010	-25	30	72	82
5012	-43	-63	78	109
5013	-3	-11	72	72
5023				
6017	-7	17	29	34
6029				
7001	23	16	-6	29
7003	66	4	-18	68
7005	42	18	29	54
7007	35	12	18	41
7009	31	-18	-4	36
7016	-175	427	25	462
7026	53	-21	-11	58
8001	-15	-32	-20	40
8002	13	-58	2	59
8005	39	13	-13	43
8009	-46	31	32	64
8012	-35	12	30	48
9001	6	26	-21	34
9002	-6	-89	-80	120
9003	-11	-9	4	15
9006	33	-23	12	42
9011	31	-28	-36	55
9031	29	-8	693	693
root mean square errors				
	96	78	117	

Table A7.6

test no. 101-60-g

ptno	dx	dy	dz	vector
1005	37	-4	6	38
1013	15	-3	-67	68
1015	-41	120	-61	141
1022	71	6	9	72
1024				
2002	36	11	21	43
2004	8	-4	9	13
2006	-36	-28	-36	58
2017	-7	15	-17	24
3001	-31	11	-34	47
3003	-5	-17	-27	32
3016	-102	86	23	136
3018	218	90	-236	333
4006	-32	-48	30	65
4014	18	-66	74	101
4015	-2	-25	31	40
4022	-399	379	-5	550
4026	5	-27	0	28
5002	81	-17	50	96
5010	-6	11	15	20
5012	12	-42	58	72
5013	8	-19	28	34
5023	-9	2	39	40
6017	7	-16	-4	18
6029	-6333	-6400	79	9004
7001	67	-4	-44	80
7003	47	-15	-33	59
7005	50	-12	-3	51
7007	51	6	7	52
7009	5	-45	2	45
7016	91	54	-37	112
7026	68	-34	-21	79
8001	11	-34	-6	37
8002	1	11	-31	33
8005	57	22	-65	89
8009	74	-15	1	76
8012	-35	-21	-1	41
9001	-7	41	-55	69
9002	-23	17	-12	31
9003	-21	22	4	31
9006	-25	50	17	58
9011	19	24	-11	33
9031	10	20	732	733
root mean square errors				
	969	978	122	

Table A7.7

test no. 112-60-g

ptno	dx	dy	dz	vector
1005	12	-25	-38	48
1013	5159	-2540	39	5750
1015				
1022	62	-22	45	80
1024	29	-15	-35	48
2002	-1	-8	-7	11
2004	-14	-23	51	57
2006	-18	-16	-40	47
2017	-86	102	3	133
3001	-22	30	-33	50
3003	-1	8	-14	16
3016	-608	447	364	837
3018	142	123	-223	292
4006	-46	-52	27	74
4014	46	-68	57	101
4015	55	-145	55	164
4022	-74	16	36	84
4026	11	-20	29	37
5002	57	-42	60	93
5010	-35	20	-14	42
5012	831	-522	122	989
5013	-2	-261	28	263
5023	-12	-5	50	52
6017	-13	-4	17	22
6029	-6400	-6238	109	8938
7001	1	-4	-67	67
7003	27	7	-37	46
7005	44	36	-4	57
7007	37	14	-12	42
7009	30	-14	-12	36
7016	-39	245	-5	248
7026	70	-32	-86	115
8001	-15	-30	-50	60
8002	-24	-30	-28	48
8005	20	20	-86	90
8009	221	-147	-29	267
8012	-47	8	-23	53
9001	4	14	-53	55
9002	-23	4	-24	34
9003	-8	5	-4	10
9006	-61	96	-19	116
9011	55	-28	-57	84
9031	27	3	684	685
root mean square errors				
	1265	1035	131	

Table A7.8

test no. 11-20-g

ptno	dx	dy	dz	vector
2002	34	-15	25	45
2004	29	-18	16	37
2006	-17	-61	-20	67
2017	80	-73	-4	108
3001	55	34	-26	70
3003	-21	-9	10	24
3016	421	-264	55	500
3018	178	108	-242	319
5002	93	-18	-43	104
5010	13	-7	-1	15
5012	30	-30	-49	65
5013	193	-9	32	196
5023	17	-20	64	70
6017	-60	-43	117	138
6029	-6407	-6076	132	8831
8001	7	-25	18	31
8002	70	-52	5	87
8005	43	44	-18	64
8009	216	-128	-39	255
8012	-36	-1	16	39
9001	41	31	-46	69
9002	4	-82	-28	87
9003	18	-7	-5	20
9006	-73	148	-5	165
9011	64	-40	-46	89
9031	39	-22	702	704
root mean square errors				
	1262	1194	153	

Table A7.9

test no. 21-20-g

ptno	dx	dy	dz	vector
2002	43	-7	7	44
2004	21	-16	13	30
2006	-5	-47	-5	48
2017				
3001	-20	7	-12	24
3003	3	10	-33	35
3016	-114	77	65	153
3018	172	126	-223	308
5002	53	-6	36	64
5010	15	14	10	23
5012				
5013				
5023	14	-20	30	39
6017	-7	3	44	44
6029	-6394	-6200	117	8907
8001	2	-16	-11	19
8002	7	-33	16	37
8005	47	3	-27	54
8009	224	-86	-7	240
8012	105	-51	11	118
9001	25	5	-49	55
9002	-1	-47	-35	59
9003	15	1	3	15
9006	-45	109	7	118
9011	47	-1	-15	49
9031	27	-24	697	698
root mean square errors				
	1256	1217	147	

Table A7.10

test no. 41-20-g

ptno	dx	dy	dz	vector
2002	21	-24	-34	47
2004	47	-47	-2	66
2006	-28	-56	-43	76
2017				
3001	-10	1	-43	44
3003	-34	-1	23	41
3016				
3018				
5002	64	-25	14	70
5010	11	-12	70	72
5012				
5013				
5023				
6017				
6029				
8001	19	-33	-12	40
8002	20	-58	3	62
8005	76	7	-24	80
8009	360	-193	17	409
8012				
9001	43	19	-8	48
9002	16	-37	-12	42
9003	28	11	21	37
9006	-105	193	38	223
9011	51	-1	18	54
9031				
root mean square errors				
	79	58	23	

Table A7.11

test no. 51-20-g

ptno	dx	dy	dz	vector
2002	29	-12	3	32
2004	19	-18	7	28
2006	-25	-56	-19	64
2017	-24	69	29	78
3001	68	39	-38	87
3003	7	-8	-38	39
3016	-103	80	22	132
3018	153	123	-242	312
5002	67	0	12	68
5010	6	18	58	61
5012	-31	-73	-8	79
5013	17	18	18	30
5023	21	-33	28	48
6017	0	4	27	27
6029				
8001	7	-33	-22	40
8002	4	-22	-25	34
8005	28	33	-22	49
8009	225	-113	-34	254
8012	-15	-14	5	21
9001	26	20	-41	52
9002	8	-63	-36	73
9003	22	3	2	23
9006	-25	92	-34	101
9011	52	-17	-34	65
9031	59	-26	670	674

Table A7.12

test no. 72-20-g

ptno	dx	dy	dz	vector
2002	25	-9	2	27
2004	61	-9	25	66
2006	-26	-41	-9	50
2017				
3001	58	43	-15	74
3003	5	-7	-9	12
3016	-110	84	27	141
3018	213	45	-238	323
5002	76	-4	36	84
5010	-38	59	39	80
5012				
5013	17	7	20	27
5023				
6017	-3	-2	47	47
6029	-6374	-6218	125	8906
8001	11	-12	8	18
8002	38	-37	2	53
8005	57	47	-14	75
8009	64	-11	-8	65
8012				
9001				
9002				
9003				
9006				
9011				
9031	36	39	724	726
root mean square errors	1251	1220	152	

Table A7.13

test no. 74-20-g

ptno	dx	dy	dz	vector
2002	30	-16	5	34
2004	40	-24	26	54
2006	-12	-43	2	45
2017				
3001				
3003	-39	-47	-23	65
3016				
3018	150	114	-221	290
5002	42	-3	67	79
5010	15	5	61	63
5012	-27	-74	33	86
5013	17	-15	51	56
5023				
6017				
6029				
8001	26	-30	32	51
8002	-13	-15	44	49
8005	65	21	-8	69
8009	-13	41	6	43
8012	-6	2	24	25
9001	13	19	-30	38
9002	-1	-67	-60	91
9003	2	3	2	4
9006	42	-10	7	43
9011	41	-3	-24	48
9031	46	-14	677	678
root mean square errors				
	40	35	143	

Table A7.14

test no. 101-20-g

ptno	dx	dy	dz	vector
2002	20	4	6	21
2004	16	-11	15	25
2006	-12	-34	9	37
2017	14	43	25	52
3001	-23	1	-15	28
3003	10	-15	-19	26
3016	-109	88	21	141
3018	210	97	-235	330
5002	114	-21	23	118
5010	4	18	67	70
5012	25	-24	38	51
5013	28	3	15	32
5023	26	-8	41	49
6017	8	-7	18	21
6029	-6323	-6383	93	8985
8001	13	-35	-1	37
8002	18	16	-2	24
8005	75	23	-36	86
8009	76	-17	-5	78
8012	-37	5	-11	39
9001	16	24	-53	61
9002	4	2	-38	38
9003	13	9	-10	19
9006	0	47	25	53
9011	33	-3	-24	41
9031	19	3	701	701
root mean square errors				
	1241	1252	148	

Table A7.15

test no. 112-20-g

ptno	dx	dy	dz	vector
2002	28	0	-11	30
2004	13	-3	-7	16
2006	-11	-32	-25	42
2017	-19	72	9	75
3001	-7	22	-20	30
3003	-7	6	2	10
3016	-579	435	363	810
3018	130	129	-214	282
5002	35	-9	37	52
5010	11	10	-17	22
5012	820	-507	143	975
5013	15	-277	6	278
5023	0	4	37	38
6017	-10	-10	44	46
6029	-6356	-6254	111	8917
8001	13	-36	-19	43
8002	5	-34	-11	36
8005	41	21	-48	67
8009	255	-154	-25	299
8012	-17	-25	-3	30
9001	34	8	-49	60
9002	11	-17	-26	33
9003	18	6	9	21
9006	-31	95	-10	100
9011	67	-28	-34	80
9031	45	-13	692	694
root mean square errors				
	1263	1236	165	

Table A7.16

test no.	41-60-L				
1005	39	-1	5	39	
1013					
1015					
1022					
1024					
2002	18	6	-27	33	
2004	40	17	13	45	
2006	11	-61	-23	66	
2017					
3001	4	19	-38	43	
3003	24	-29	-28	47	
3016					
3018					
4006	-12	-25	51	58	
4014					
4015					
4022					
4026					
5002	15	13	33	39	
5010	-29	-1	62	68	
5012					
5013					
5023					
6017					
6029					
7001	-1	21	9	23	
7003	36	30	-5	47	
7005					
7007	16	41	3	44	
7009	36	27	20	49	
7016					
7026					
8001	23	2	-14	27	
8002	47	-29	-4	55	
8005	22	42	-27	55	
8009	278	79	23	290	
8012					
9001	-8	37	-35	52	
9002	29	-46	3	54	
9003	-18	12	28	35	
9006	-243	86	69	267	
9011	33	37	11	51	
9031					
root mean square errors					
	59	27	22		

Table A7.17

test no.	73-60-L			
1005	28	1	-1	28
1013				
1015	-95	-16	-10	97
1022	74	48	42	98
1024	47	-5	43	64
2002	20	17	-9	28
2004	32	17	23	43
2006	27	-70	20	78
2017	-32	6	28	43
3001	11	60	-18	64
3003	-32	31	-22	50
3016	-133	-49	81	163
3018	49	11	57	76
4006	18	-39	17	46
4014	43	-10	34	56
4015	-232	79	110	269
4022	-87	-15	36	95
4026	5	18	35	40
5002	57	30	44	78
5010	-11	1	37	39
5012				
5013	2	5	62	62
5023	-76	-185	53	207
6017	4	6	30	31
6029				
7001	23	35	2	42
7003	23	45	-31	59
7005				
7007	16	41	3	44
7009	32	18	4	37
7016				
7026	63	60	-45	98
8001	19	-19	20	33
8002	23	-25	15	37
8005	17	48	-35	62
8009	32	38	35	61
8012	-13	-42	38	58
9001	-4	21	-41	46
9002	-15	-2	-4	16
9003	-6	3	35	36
9006	-99	19	29	105
9011	24	9	44	51
9031	20	6	0	21
root mean square errors				
	56	42	36	

Table A7.18

test no.	74-60-1			
1005	26	-2	46	53
1013				
1015				
1022	40	66	51	93
1024	24	2	38	45
2002	-512	-268	32	579
2004	24	10	37	45
2006	7	-52	21	57
2017				
3001				
3003	1	-17	-12	21
3016				
3018	-34	-20	-1	39
4006	-37	-30	60	77
4014	49	-15	47	70
4015	-21	-49	21	57
4022	-93	-11	72	118
4026	-3	0	71	71
5002	33	48	63	86
5010	-45	13	44	64
5012	4	-82	97	127
5013	-4	3	77	77
5023				
6017	9	16	7	20
6029				
7001	-8	39	25	47
7003	39	50	1	63
7005	14	51	51	73
7007	7	39	42	58
7009	19	18	32	41
7016	28	57	20	67
7026	53	21	-13	58
8001	-3	-17	25	30
8002	35	-36	27	57
8005	16	48	13	52
8009	-68	-19	27	76
8012	-28	-22	26	44
9001	-22	15	7	28
9002	51	-77	-27	96
9003	-5	-2	28	29
9006	23	6	31	39
9011	30	7	18	36
9031	34	12	688	689
root mean square errors				
	84	52	111	

Table A7.19

test no.	41-20-L			
2002	32	4	-27	42
2004	58	17	-11	61
2006	21	-50	-32	63
2017				
3001	-8	16	-18	25
3003	-7	-18	53	56
3016				
3018				
5002	87	53	12	103
5010	12	4	62	63
5012				
5013				
5023				
6017				
6029				
8001	34	-11	-1	36
8002	48	-34	-1	59
8005	42	54	-21	72
8009				
8012				
9001	17	38	-9	43
9002	43	-28	2	51
9003	22	25	23	40
9006				
9011	31	23	28	48
9031				
root mean square errors				
	29	23	20	

Table A7.20

test no.	73-20-L				
2002	20	201	23	203	
2004	34	12	28	46	
2006	19	-63	20	69	
2017	-32	6	18	37	
3001	11	60	2	61	
3003	-19	9	3	21	
3016	-133	-49	76	161	
3018	44	25	2	51	
5002	55	35	39	76	
5010	-11	17	27	34	
5012					
5013	11	9	42	44	
5023	-57	-178	63	197	
6017	0	20	35	40	
6029					
8001	-11	7	25	28	
8002	21	-20	5	29	
8005	23	60	0	64	
8009	45	26	20	56	
8012	-13	-26	38	48	
9001	3	29	-26	39	
9002	11	-4	-44	46	
9003	7	8	5	12	
9006	-90	38	24	101	
9011	21	18	24	37	
9031	20	5	704	704	
root mean square errors					
	40	60	141		

Table A7.21

test no.	74-20-1				
2002	34	11	18	40	
2004	49	7	22	54	
2006	28	-51	15	60	
2017					
3001					
3003	1	-74	-18	76	
3016					
3018	9	-13	-8	18	
5002	50	30	42	72	
5010	-9	7	43	44	
5012	37	-80	26	92	
5013	14	-2	49	51	
5023					
6017					
6029					
8001	13	-12	29	34	
8002	3	-33	35	48	
8005	28	70	14	77	
8009	-37	10	17	42	
8012	-28	3	22	36	
9001	-6	30	-1	31	
9002	51	-56	-32	82	
9003	3	9	17	19	
9006	25	22	31	45	
9011	31	18	-3	36	
9031	36	17	690	691	
root mean square errors	26	32	137		

LIST OF THE OEEPE PUBLICATIONS

State — November 1987

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'aérottriangulation 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'aérottriangulation. 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 Réseau 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.“ — Frankfurt a. M. 1985, 228 pages with 102 figures and 30 tables.

- 13 *Timmerman, J.; Roos, P. A.; Schürer, K.; Förstner, R.*: On the Accuracy of Photogrammetric Measurements of Buildings — Report on the Results of the Test "Dordrecht", Carried out by Commission C of the OEEPE. — Frankfurt a. M. 1982, 144 pages with 14 figures and 36 tables.
- 14 *Thompson, C. N.*: Test of Digitising Methods. — Frankfurt a. M. 1984, 120 pages with 38 figures and 18 tables.
- 15 *Jaakkola, M.; Brindöpke, W.; Kölbl, O.; Noukka, P.*: Optimal Emulsions for Large-Scale Mapping — Test of "Steinwedel" — Commission C of the OEEPE 1981–84. — Frankfurt a. M. 1985, 102 pages with 53 figures.
- 16 *Waldhäusl, P.*: Results of the Vienna Test of OEEPE Commission C.— *Kölbl, O.*: Photogrammetric Versus Terrestrial Town Survey. — Frankfurt a. M. 1986, 57 pages with 16 figures, 10 tables and 7 annexes.
- 17 *Commission E of the OEEPE*: Influences of Reproduction Techniques on the Identification of Topographic Details on Orthophotomaps. — Frankfurt a. M. 1986, 138 pages with 51 figures, 25 tables and 6 appendices.
- 18 *Förstner, W.*: Final Report on the Joint Test on Gross Error Detection of OEEPE and ISP WG III/1. — Frankfurt a. M. 1986, 97 pages with 27 tables and 20 figures.

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 D). — 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'O.E.E.P.E. — Florence 1959, 16 pages with 109 tables.

— *Trombetti, C.; Fondelli, M.*: Aérotriangulation analogique solaire. — Firenze 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. Vermess.-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“

Gotthardt, E.: „Erfahrungen mit analytischer Einpassung von Bildstreifen.“ — *Nachr. Kt.- u. Vermess.-wes.*, R. V, Nr. 12, Frankfurt a. M. 1965, 14 pages with 2 figures and 7 tables.

— „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.

- „OEEPE — Sonderveröffentlichung Nr. 5“

Förstner, R.: „Über die Genauigkeit der photogrammetrischen Koordinatenmessung in bergigem Gelände. Bericht über die Ergebnisse des Versuchs Reichenbach der Kommission C der OEEPE.“ — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1969, Part I: 74 pages with 9 figures; Part II: 65 tables.

- „OEEPE — Sonderveröffentlichung Nr. 6“

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.

- „OEEPE — Sonderveröffentlichung Nr. D-7“

Förstner, R.: „Das Versuchsfeld Reichenbach der OEEPE.“ — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1972, 191 pages with 49 figures and 38 tables.

- „OEEPE — Sonderveröffentlichung Nr. D-8“

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.
Harry, 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.

- „OEEPE — Sonderveröffentlichung Nr. D-11“

Schulz, B.-S.: „Vorschlag einer Methode zur analytischen Behandlung von Reseauaufnahmen.“ — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1976, 34 pages with 16 tables.

- „OEEPE — Sonderveröffentlichung Nr. D-12“
Verlaine, R.: „25 Jahre OEEPE.“ — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1980, 53 pages.

- „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.

- „OEEPE — Sonderveröffentlichung Nr. D-14“
Spiess, E.: „Fortführung der Topographischen Karte 1 : 25 000 mittels Photogrammetrie“ (in Vorbereitung).

- „OEEPE — Sonderveröffentlichung Nr. D-15“
Timmerman, J.; Roos, P. A.; Schürer, K.; Förstner, R.: „Über die Genauigkeit der photogrammetrischen Gebäudevermessung. Bericht über die Ergebnisse des Versuchs Dordrecht der Kommission C der OEEPE.“ — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1983, 131 pages with 14 figures and 36 tables.

- „OEEPE — Sonderveröffentlichung Nr. D-16“
Kommission E der OEEPE: „Einflüsse der Reproduktionstechnik auf die Erkennbarkeit von Details in Orthophotokarten.“ — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1986, 130 pages with 51 figures, 25 tables and 6 annexes.

- „OEEPE — Sonderveröffentlichung Nr. D-17“
Schürer, K.: „Über die Genauigkeit der Koordinaten signalisierter Punkte bei großen Bildmaßstäben. Ergebnisse des Versuchs „Wien“ der Kommission C der OEEPE.“ — Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1987, 84 pages with 3 figures, 10 tables and 42 annexes.

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