OPTIMAL EMULSIONS FOR LARGE SCALE MAPPING

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1. Test "Steinwedel" – description of the test-project

1981 the OEEPE – Organisation Européene d'Etudes Photogrammétriques Expérimentales – concluded to carry out a test with the working-title "Optimal Emulsions for Large Scale Mapping".

The aim was to test different emulsions for large scale plotting and mapping. There were 3 main aims in the foreground:

- Determination of the precision of numerical plotting using different film-emulsions, in particular the influence of target-color and underground.
- Photographic-physical investigations of the different emulsions and the different targets;
- Checking the reliability of plotting the different targets and topographic objects in the different emulsions.

The preparatory work started in April 1982, the analysis of the plotting work in respect to the main aims could be finished in January 1984.

The test-field of about 400 x 600 m is located east of Hanover, FRG (page 2); the pilot centre was the National Survey of Lower Saxony, Hanover. Besides the 113 targets with different colors there belong to it 86 roof-points and topographic objects. The most of them have been determined by high precise terrestrical survey (page 3).

After selection of 9 emulsions, which are of interest for large scale mapping – 5 Black-and-White-, 4 Color-emulsions – the photo-flights were carried out in May 1982, scale = 1 : 4000, f = 30 cm (page 4). As the result there are 17 photo-strips, which differ not only by the 9 emulsions but also by different light – open sky or overcast sky – and by different exposure-times (plus-minus 1 aperture).

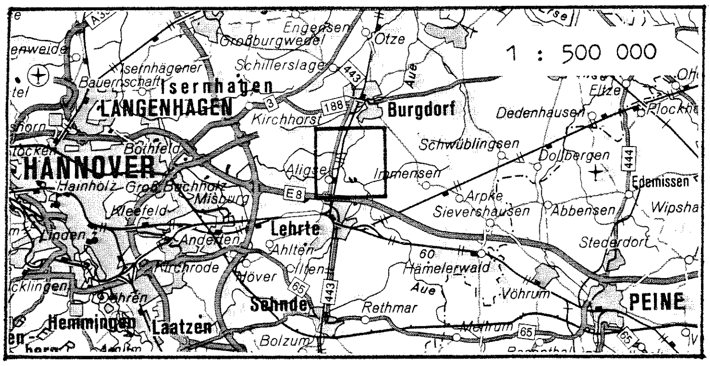
The now produced photo-material permits plotting of 54 different stereomodels. Between autumn 1982 and autumn 1983 the plotting of this material – about 3–4 times per model – has been carried out by the 18 participants from 7 member-countries of the OEEPE. Among the 18 used stereo-plotting instruments there were 11 analytical plotters of new design. In total the 54 models were plotted 115 times.

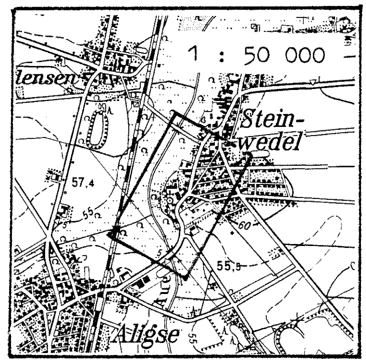
The photo-flights were carried out by Hansa Luftbild, Münster (HL) and Kirchner & Wolf, Hildesheim (KW). The manufacturers KODAK and AGFA made all the films avaiable for the test free of charge.

The following report of analysis deals with the results in respect to the items mentioned above:
in chapter 5: "Geometrical aspects" (Noukka),
in chapter 6 + 7: "Photographic physical quality" and "Signalized points in different emulsions" (Kölbl),
and in chapter 8: "Reliability of interpretation" (Brindöpke).
A summary is given on page 10.

2. The location of the test area

The test-area is located in the small village "Steinwedel" east of Hanover. It has flat terrain, is built in an open way for one half and shows agricultural use for the other half. All possibilities wanted for locating targets and for selection of topographical features were avaiable. The test-area had been arranged in such a way, that its size of 400 by 600 m could be covered by one model 1 : 4000.



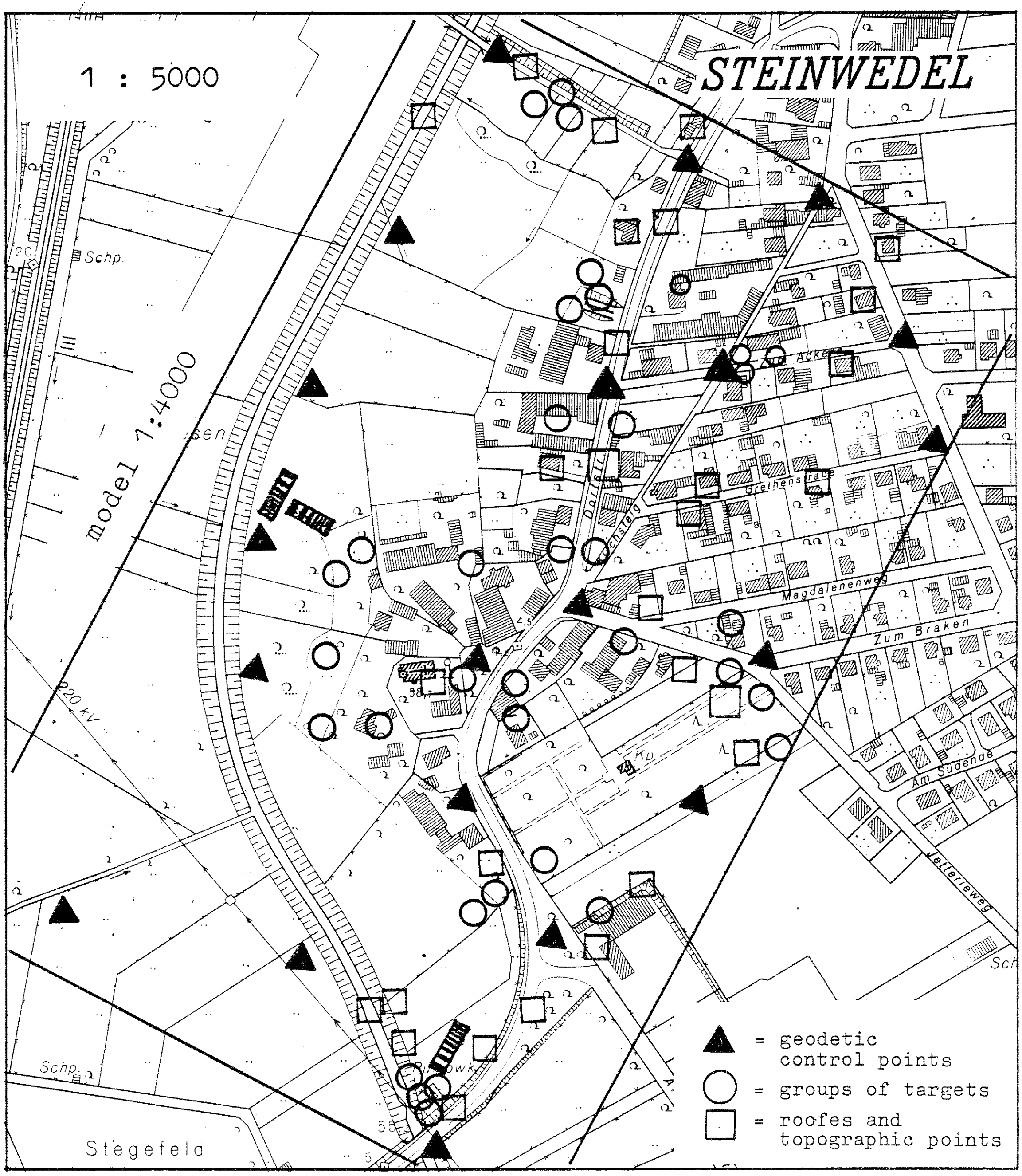


3. Description of the test field

The testfield is covered by 20 geodetic control points (15 surrounding the area, 5 in the interior). Their standard deviation of coordinates is 0,003 m.

The test can be performed by 199 points in total: 113 points with targets (36 white, 36 red-orange, 21 yellow, 20 black) and that on different underground (27 in grass land, 26 on soil, 24 on asphalt/ concrete, 24 on red roofes, 12 in shadow); size of targets = 12 x 12 cm. Furtheron there were selected 86 topographical points, of them 54 roof-points, besides building corners, fence corners, hedge corners, stakes, pole foot points, road edge points, points in the waterfront and others). The standard deviation of coordinates for all topographical points is 0,01 m.

At two places test-plates were layed out which should be used for determination of the resolving power of the different emulsions.



4. Photoflights and restitution

Table 1: Used Emulsions

Nr		Emulsion	Manu-fact.	Properties AFS/EASF	L/mm	base mm	Characterization grain	speed	contrast
1	Black+ White	Aviphot PAN 200 PE	Agfa	500	50	0,1	fine	high	good
2		PLUS-X Aerographic 2402	Kodak	200	50	0,1	medium	medium	medium
3		DOUBLE-X Aerographic 2405	Kodak	500	50	0,1	fine	high	good
4		Panatomic-X Aerocon II,3412	Kodak	40	160	0,06	v.fine	less	high
5		High Definition Aerial 3414	Kodak	8	250	0,06	extr.fine	slow	strong
6	Color	Aerochrome MS 2448 \SO-397	Kodak	32	40	0,1	fine	medium	medium
7		Ektachrome EF,Aerographic\	Kodak	64	40	0,1	v.fine	medium	low
8		Aerocolor Negative 2445	Kodak	100	40	0,1	v.fine	high	wide exp.latid.
9		Aerochrome Infrared 2443	Kodak	40	32	0,1	fine	medium	high

Table 2: Results of Photo-Flights - Photomaterial avaiable

Flight Strip-Nr.	Emulsion	Date 1982	Flight Com-pany	Exposure Time	Apert.	Remarks	Number of models	Number of plott. models
1	PAN 200	12.May	HL	1/1000	8	normal, good	3	9
2	PAN 200	18.June	HL	1/600	6.5	overcast sky,good	3	6
3	PLUS X	12.May	KW	1/500	5.6	normal, good	2	6
4	DOUBLE X	12.May	KW	1/700	5.6	normal, good	2	4
5	DOUBLE X	17.May	KW	1/500	5.6	overcast sky,weak	3	6
6	Panatomic	12.May	HL	1/700	5.6	underexposed, sharp	2	6
				1/300	"	normal exposure	3	6
				1/200	"	overexposed, unsharp	1	2
7	High Def.	12.May	KW	1/200	5,6	normal exposed, unsh.	2	3
				1/400	"	underexposed,	2	4
8	C-Dia 2448	12.May	KW	1/500	5,6	normal, good	2	5
9	Dia 2448	27.May	HL	1/400	5,6	normal, optimal	1	3
				1/500	"	underexposed, good	1	2
				1/800	"	overexposed	2	5
10	Dia 2448	17.May	KW	1/300	5,6	overcast sky, good	2	5
11	Dia SO-397	12.May	HL	1/1000	8	normal, good	2	5
				1/1000	11	underexposed	2	3
12	Dia SO-397	27.May	HL	1/1000	8	normal, v.good	2	2
				1/1000	11	underexp.,very good	1	3
13	Dia SO-397	4.June	KW	1/200	5,6	overexposed, bad	3	6
14	Dia SO-397	18.June	HL	1/500	8	overcast sky, dark	1	1
				1/1000	8	underexp.,bad	2	3
15	Dia SO-397	18.June	KW	?	8	overcast sky,bad	3	5
16	C-Negativ	12.May	KW	1/400	5,6	normal,very good	2	6
17	CIR-Infrar	12.May	HL	1/300	5,6	normal	2	3
				1/700	"	underexp.very good	2	4
				1/200	"	overexp., light	1	2
1-7 = black&white 8-17 = color			HL = Hansa Luftbild, Münster KW = Kirchner & Wolf, Hildesheim			Σ:	54	115

Table 3: Participants

Coun-try	Nr.	Name	Instruments	Ø-float. mark	number of plotted models
CH	34	Institut Photogram., Zürich	Wild AC 1	25 µm	5
	35	Institut Photogram., Lausanne	Wild BC 1	25	5
D	01	Landesvermessung Hannover	Zeiss-Planicomp	40	21
	02	Inst.Angew.Geodäsie,Frankf.	Zeiss-Planicomp	40	6
	03	Landesvermessungsamt Bonn	Zeiss-Planicomp	40	6
	04	Landesvermessungsamt Kiel	Wild AMH, RAP	45	5
	05	Landesvermessungsamt Wiesbaden	Zeiss-Planicomp	20	5
	06	Landesvermessungsamt München	Zeiss-Planicomp	40	5
	07	LAmt Flurbereinigung Ludwigsbg.	Zeiss-Planicomp	20	5
	08	Fa.Kirchner&Wolf, Hildesheim	Zeiss-Planimat	40	5
	09	Fa. Rheinbraun, Köln	Zeiss-Planimat	40	5
DK	21	Photogram. Labor. Uni Aalborg	Zeiss-Planimat	40	5
F	23	IGN, Paris	Matra-Traster	?	3
GB	24	School Military Survey,Newbury	Wild A 8	70	5
	25	Clyde Surveys Ltd.,Maidenhead	Wild A 8	70	10
	26	Dep.Photogrammetry,Uni London	Kern DSR 1	25	5
I	29	Instituto Topografia, Milano	Zeiss-Planicomp	40	9
NL	22	ITC, Enschede	Wild A 10	40	5
					115

5. Geometrical Aspects

In this part of the study the influence of emulsion, flight weather and target colour into the achieved geometric accuracy of the photogrammetrically determined points was investigated. The precisely measured geodetic coordinates of the ground stations formed the reference base of the study.

Altogether 20 models were included into this part of the test. The observations were carried out with stereocomparator Zeiss PSK 1, and in corresponding calculations the method of bundle block adjustment with additional parameters was applied. The material was still handled with the method of the finite elements in order to avoid the systematic errors. The main results of the adjustments are shown in the table 4.

Table 4: The main results of the photogrammetric adjustments

Flight Model	Emulsion	Block Adjustment: Nr.of Control Points	Nr.of Check Points	σ_0 (µm)	Discrepancies (RMSE) at the Check Points (cm): Before Correction of the Systematic Errors X	Before Y	After X	After Y
normal exposure								
1- 31/33	PAN 200	19	71	4.6	2.0	2.4	1.4	2.0
3- 82/83	PLUS X	19	69	4.4	2.5	2.8	2.2	2.5
4- 66/67	DOUBLE X	20	73	4.1	2.1	2.6	1.8	2.2
6- 20/22	Panatomic 3412	17	76	4.4	2.3	2.6	1.8	1.9
7-132/133	HD 3414	17	53	4.0	2.3	2.5	1.7	1.9
8- 94/95	Dia 2448	19	73	3.9	2.1	2.9	1.7	2.4
12- 32/34	Dia SO 397	20	67	4.7	2.2	3.2	1.6	1.9
16-111/112	Neg. 2445	11	52	6.0	2.5	3.4	1.9	2.1
9- 40/42	Dia 2448	15	63	4.1	2.1	2.3	1.6	1.9
17- 18/20	IR 2443	18	74	4.3	2.3	2.7	1.7	2.1
underexposed								
9- 13/15	Dia 2448	15	56	4.0	2.5	2.9	1.4	1.7
17- 24/26	IR 2443	12	58	3.3	2.3	2.9	1.8	1.7
17- 23/25	IR 2443	18	69	3.5	1.7	2.5	1.2	2.2
6- 28/30	Panatomic 3412	20	84	4.1	2.0	2.4	1.6	1.9
overexposed								
6- 34/36	Panatomic 3412	18	60	4.9	2.4	2.7	1.7	2.2
17- 29/31	IR 2443	13	44	4.4	2.6	3.8	1.9	2.9
overcast sky								
2- 25/27	PAN 200	14	43	4.7	2.8	3.5	2.0	2.8
5- 4/5	DOUBLE X	12	56	5.2	2.1	2.2	1.7	1.5
10- 26/27	Dia 2448	16	67	5.3	3.0	2.4	1.3	1.9
15- 5/6	Dia SO 397	12	41	5.8	3.5	4.4	2.7	3.7

By means of statistical methods was studied whether the differences in accuracy are significant in regard to various parameters. Because of the nature of the material and the number of observations, the analysis of variance, the F- test of Fischer, the Student T- test and nonparametric test of Mann-Whitney were choosen as methods of the statistical investigations.

From the studies of the geometrical accuracy we may conclude: In optimal conditions there are no significant differences in measurability between emulsions as far as the geometrical quality is concerned. In infavourable conditions there exist some differences in this regard. This may have been, however, caused by the fact that number of observations and in consequence the reliability of the results have been reduced so that there are not enough base for reliable statistical conclusions.

6. Photographic physical quality of the test material

Main parameters for the characterization of the photographic image quality are resolution or the contrast transfer function, density and contrast. The contrast transfer function respectively ist Fourier transform the spread functions have been determined with special test targets during flight. With some simplification the spread of the different films can be given by the following figures:

Black-and-white film (without Panatomic-X film): $\sigma = 25-28\ \mu m$.
Kodak Panatomic-X film: $\sigma = 22-27\ \mu m$.
Color films: $\sigma = 32-40\ \mu m$.

σ has been chosen in a way that the inverse $1000/\sigma$ corresponds to the resolution in lines/mm for a contrast of about 1 : 3.

One remarks a considerable higher resolution of black and white films compared to color films; remarkable too is in particular the high performance of the Panatomic film.

The aim of the density measurements was to determine the optimal exposure of a film for point measurements. Of special interest are in this context films which have been flown with different exposures. When the density of different objects is compared with the measuring precision, respectively the quality code, one remarks that the underexposed Panatomic-Film gives considerable better results than the overexposed film (cf. fig.)

According to these diagrams it can be seen that the Panatomic-X film supplies the best measuring results, when asphalt streets are exposed to a density of 0.7 to 0.9; points in shadow areas however can hardly be measured under these conditions. In order to ensure for these points also an adequate quality, a longer exposure is preferable and density values between 1.0 and 1.2 for streets should be aimed for. Concurrently, shadow areas would reach densities between 0.3 and 0.4.

Similar statements could be made for other films.

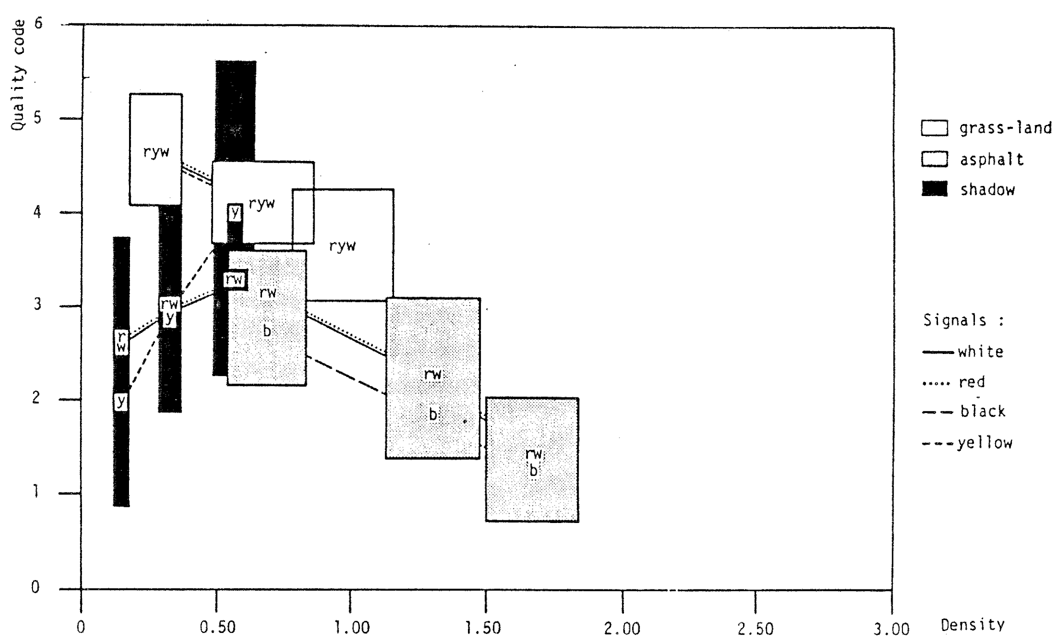
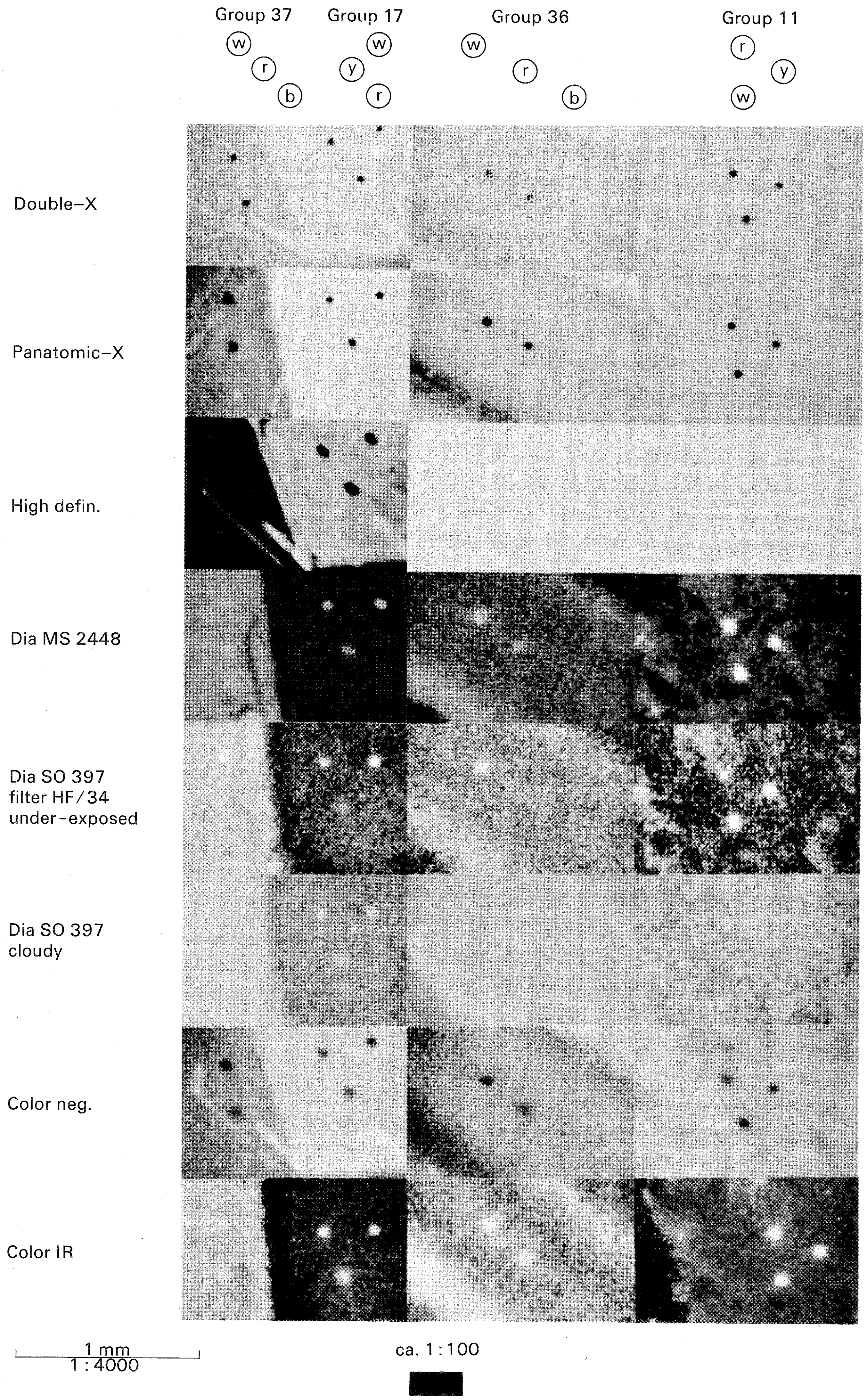


Fig.: Panatomic-X film

Variation of the density of the background of signals and of the quality code when choosing different exposures of the film. The left badge refers to the underexposed film, the middle one to the normally exposed and the right one to the overexposed film. The centre of the areas plotted, marked by letters w = white, r = red, b = black or y = yellow, corresponds to the mean value of the group; the right and the left border indicate the spread computed according to the mean square devinition from the mean value. The tone of the badge indicates the background of the signals. The connection lines show the tendency as for the variation of the density and the quality code when are overexposed, normally exposed or underexposed.


Group 37
w
r
b
Group 17
w
y
r
Group 36
w
r
b
Group 11
r
y
w
Double–X
Panatomic–X
High defin.
Dia MS 2448
Dia SO 397
filter HF/34
under-exposed
Dia SO 397
cloudy
Color neg.
Color IR
1 mm
1 : 4000
ca. 1 : 100

7. Metric results of signalized points in different emulsions

When analysing the precision of the different measurements one has at the first glance difficulties, to notice remarkable differences between the various centers and various films. A more detailed analysis shows however that the resulting measurements have considerable systematic components. In order to reduce these systematic components the residual errors have been approximated by an interpolation surface defined by finite elements (mash-width 50 m). The remaining random errors allow some quite interesting statements (cf. table 5). One remarks that the observation-errors derived from double measurements gets rather close to the residual errors after correction of the systematic components. Futhermore it is noticible that a great number of analytical plotters gives rather uniform results between ± 1.7 and ± 2.0 cm and only 4 instruments give considerable higher measuring precision of ± 1.4 cm.

When comparing these instruments with table 3, one remarks that the higher precision was obtained with instruments disposing on a floating mark of 25 μm whereas the other instruments have larger floating marks.

A more profond analysis shows that for most of the black and white films the signalized points in the photographs are smaller than 40 μm. Only in the color film due to the lower resolution and the larger spread a somewhat larger signal size is obtained. This reflects also in the measuring presision. When all measurements, executed on analytic plotters, are analyzed, one remarks that the measuring precision on color film is about 10% higher than on black and white films. When doing the same analysation for models measured with a smaller floating mark one gets the reversed effect. These considerations show how careful one should be, when drawing conclusions as for better measuring conditions with different films.

The color of the signal seems to have minor importance; only black signals show considerable lower measuring precision than red, white or yellow marks.

It might be disappointing that the Panatomic-X film did not give the very best results. It seems that the precision of the control points measured in the terrain do not allow to get considerable better results for this film; and at least for the plotters with floating marks of 25 μm the limited precision of the test field has to be taken into consideration.

Center Instrument	Number of models	Observation errors mean variance	Coordinate residuals mean variance	Number of points mean variance
1 Planicomp	22	1.2 ± 0.2	1.7 ± 0.2	72 ± 11
2 Planicomp	6	1.5 ± 0.5	1.7 ± 0.2	71 ± 8
3 Planicomp	6	1.5 ± 0.1	1.8 ± 0.1	77 ± 6
6 Planicomp	5	2.0 ± 0.5	2.1 ± 0.5	65 ± 16
29 Planicomp	9	1.5 ± 0.4	1.7 ± 0.2	60 ± 12
23 Traster	3	1.9 ± 0.5	1.7 ± 0.2	47 ± 8
26 DSR 1	5	1.2 ± 0.1	1.8 ± 0.2	66 ± 15
Hel DSR 1	13	-	2.0 ± 0.4	72 ± 12
Hel PSK	19	-	1.8 ± 0.2	60 ± 11
5 Planicomp	5	1.0 ± 0.3	1.4 ± 0.3	62 ± 15
7 Planicomp	5.	1.1 ± 0.2	1.4 ± 0.5	63 ± 15
34 AC 1	5	1.1 ± 0.3	1.4 ± 0.2	56 ± 16
35 BC 1	5	0.8 ± 0.2	1.4 ± 0.3	76 ± 8

Table 5: Recapitulation of the measuring accuracy of the different centers with different instruments:
1. group: floating mark = 40 μm
2. group: variable floating mark
3. group: floating mark < 30 μm

8. Investigation of the reliability of photointerpretation

The reliability of the photointerpretation has been investigated for the different emulsions and exposure-dispositions:

– in respect to the loss of points because of unsufficient possibility of identification;

– in respect to the accuracy of addressing topographical points.

For the percentage of falling out of points (loss of points) those points were considerd, which on the one hand had not been plotted at all, or on the other hand had very gross errors (see below). For the determination of the accuracy only those results are published here, which came from the 11 centers with analytical plotters. The standard deviations are calculated from residual errors against terrestrical values as a result of normal Helmert-Transformation, without eliminating systematic image errors.

The results are summarized in the table below. Standardfilms comprise the emulsions 1, 2, 3 (Black-and-White = BW), 7, 8 (Color = C-films). Special emulsions are the No. 4 and 9 (BW-Panatomic, Colorinfrared) (see page 4).

Reliability

1. With good illumination the reliability of C-films for signalized points is distinctly higher than from BW-films.
2. With bad illumination C-films even lose less reliability for all kinds of points than BW-films.
3. Compared with the standardfilms the CIR-film and specially the BW-Panatomic-film has considerable more reliability.

Accuracy

4. In respect to accuracy of signalized points there is no significant difference between BW- and C-films.
5. For signalized points even a bad illumination does not effect the accuracy in both films; bad illumination however causes for topographical points in C-films a distinct higher decrease of accuracy than in BW-films.
6. The CIR- and the BW-Panatomic-films produce too in respect to accuracy better results than standard-films.

Summary

With good illumination (open sky) colorfilms compared with black-and-white-films show only small advantage. With bad illumination (overcast sky) black-and-white-films are still superior in respect to accuracy; but they show less reliability of interpretation compared with color-films.

The special emulsion (Panatomic, CIR) deliver in total very good results.

Table 4

Illumination	Emulsion	Falling out points %				Stand.dev.coordinates [cm]			
		target	roof	top.	Σ	target	roof	top.	Σ
Sun	Standard								
	B+W	5	1	3	3	3,1	5,3	17,5	9
	Color	3	2	3	2,5	2,9	4,5	14,3	7
	Special								
	Panatomic	3	0,5	2	2	2,7	4,9	15,8	8
	Color-IR	2,5	1	1	1,5	2,7	5,0	13,0	7
	Σ	3	1	2	(2)	3	5	15	(8)
Overcast Sky	Standard								
	B+W	7	5	16	9	3,2	5,9	21,2	10
	Color	5	3	11	6	3,3	7,4	23,3	11
	Σ	6	4	13	(8)	3	7	22	(11)

9. Summary of the test results "Steinwedel"

The analysis of the 3 centers Helsinki, Lausanne and Hanover permits the following conclusions:

9.1. In general

The photo material as well as the restitution (instruments, floating marks, quality of restitution) were very unhomogeneous. The differences between the 18 centers are often larger than the differences between the used emulsions itselves.

9.2. Essential results

- With the help of the targets for determination of the resolving power we get the following values:

Black-and-white-emulsions (without Panatomic):	38 lines/mm	contrast 1 : 3
Color-emulsions:	28 lines/mm	
Black-and-white-Panatomic film:	41 lines/mm	

- In spite of this distinct differentiation for signalized points there can not be seen a significant difference between black-and-white- and color-films in respect to geometric accuracy. The standard deviations of coordinates from signalized points with sunny sky amounts to 1,5 – 2,0 cm for black-and-white- as well as for color-emulsions. That means about 4 μm in the photo scale (after elimination of systematic errors). The photogrammetric accuracy is not far away from the accuracy of terrestrical determination (± 1 cm).
- The black-and-white-Panatomic film and the Colorinfrared-film show a tendency of a higher accuracy if comparing them with black-and-white- and color-standard-films.
- Photo-flights below overcast sky or with a certain degree of overexposure procure instinctly worse results and that the more as the points have less structure or are not so much outlined.
- Also between the colors of the targets – White, Yellow, Red-orange – there is no significant difference. Black targets are of no use, even not on a bright underground. The optimal underground is grass land.
- In respect to the reliability of interpretation – of "addressing points" – there are similar results: color-films show only somewhat better results than black-and-white-films; a distinct better results we can recognize by the panatomic- and the colorinfrared-film. With overcast sky the loss of points increases two- and fourfold; with overcast sky nevertheless color-films procure better results than black-and-white-films.

9.3. Conclusions for practical work and future tests

- The test does not prove a significant profit for Color-films versus Black-and-white-films in respect to accuracy of signalized points. The reliability of interpretation proves however somewhat better in color-films. The economy of color-films in large scale plotting should be investigated furthermore in respect to topographic points (non-signalized points).
- Further investigations should be made specially in respect to the black-and-white-Panatomic- and the Colorinfrared-film.
- An important results is, that there is a higher necessitiy to order more rigorous conditions for executing photo-flights in respect to flying weather, exposure-time and developement of films.
- Future tests should limit the aims of tests working in a more severe kind than in this test "Steinwedel"; technical conditions must be decided in a more strictly way.

Details of the test "Steinwedel" will be reported in the official OEEPE-Report, which will be published end of 1984.

March 1984