14th Congress of the International Society for Photogrammetry
Hamburg 1980
Commission I
Presented Paper

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AN EMPIRICAL STUDY OF THE VISIBILITY OF TARGETS

Abstract

In the summer of 1979, an experiment to determine the factors affecting the visibility of targets was carried out on the test field of Jämijärvi. The objects of the study were the effects of the flight direction, the position in the terrain, the size and colour of the target, and the position on the image. Circular targets of different sizes and colours were placed on contrast sheets and located on the test field of Jämijärvi and in its surroundings. Aerial photography was carried out using black-and-white panchromatic film at the scale 1:8000. The image coordinates of the targets were measured and the visibility of every target was classified.
Analysis of variance and simultaneous test methods were used for the statistical analysis of the observations.

0. Introduction

For several years, the test field of Jämijärvi has been used for calibration of cameras in Finland. The location of the test field on the slope of a ridge and its use as an air field for gliders have given reason to assume that the local conditions have an effect on the poor visibility of targets in the photographies of the test field. For this reason the National Board of Survey (NBS) and the Helsinki University of Technology (HUT) decided to study how different factors affect the visibility of targets. The objects of the study were the effects of the flight direction, the position of targets in the terrain, the size and colour of the target, and the position on the image.

1. The experiment

Three different sizes of circular targets were chosen for the experiment. The diameters of the targets were 0,30 m, 0,50 m and 0,80 m and the sizes of the contrast sheets varied from 1,20 m to 1,60 m (Fig.2)

Four target colours and two contrast colours were chosen. The target colours were: white, yellow, orange, and unpainted white; the contrast colours were: black and blue. The colours were chosen from among those recommended by Hlawaty-Stickler /1/, Ackerl-Neumaier /2/, Schwidefsky-Kellner /3/, and Trinder /4/. The measuring of the colour coordinates was done in the Electrical Engineering Laboratory of the Technical Research Centre of Finland with light C [x] (Table 1).

TABLE 1. Colour coordinates

Example		Black	Blue	Yellow	Orange
Colour coordinates	x	0,312	0,237	0,428	0,552
	y	0,319	0,235	0,452	0,425
	z	0,369	0,528	0,120	0,023

Nine identical groups were built on different sides of the test field (the 10th was not a full group) and three comparison groups were built outside the test field at a distance of approximately 6 km (Fig.1).

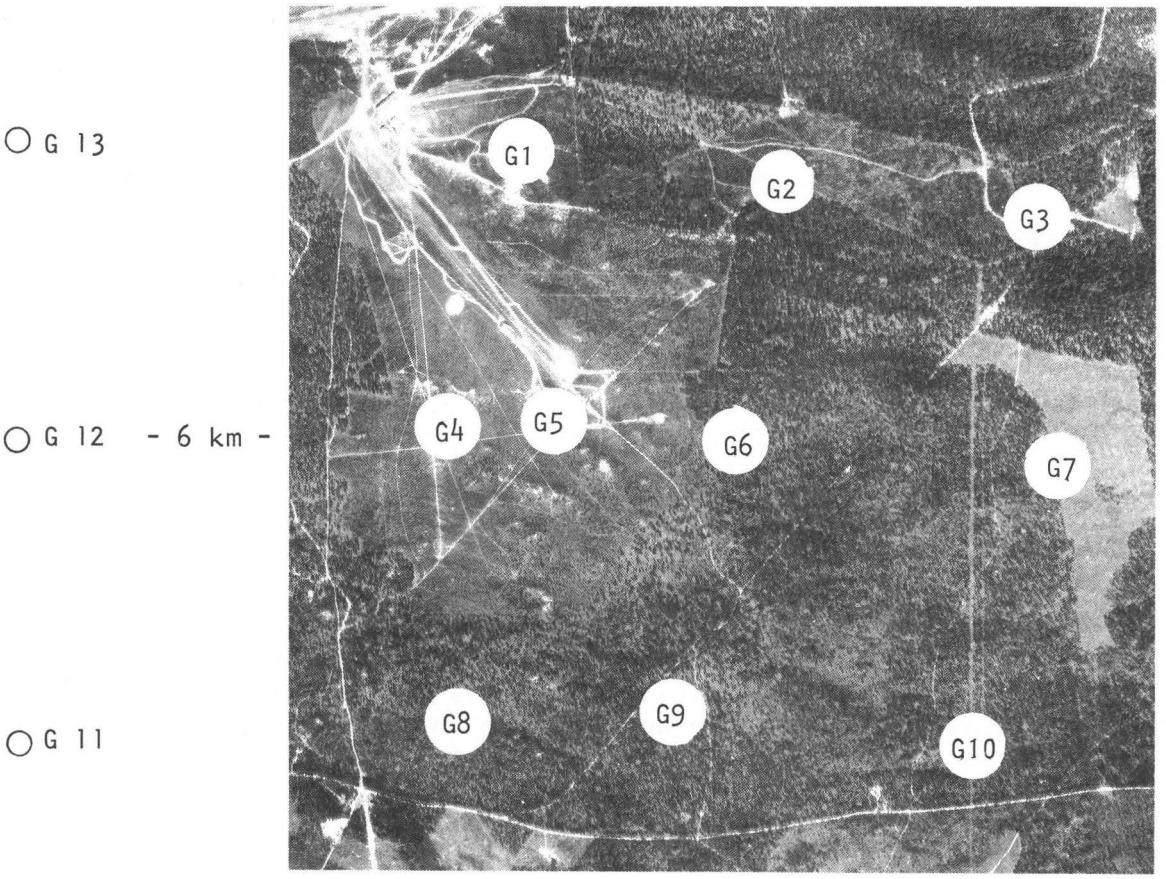


Figure 1. The location of target groups on the test field of Jämijärvi.

x) The measuring was done according to the publication n:o 15 of CIE (Colour temperature 6774K) with the instrument Spectra Pritchard model 1980A-PL, August 30, 1979 Work number SÄH 9350.

The location of different targets in the groups and their colours are shown in Fig.2. In total, 115 targets were placed on the test field and 30 targets outside it.

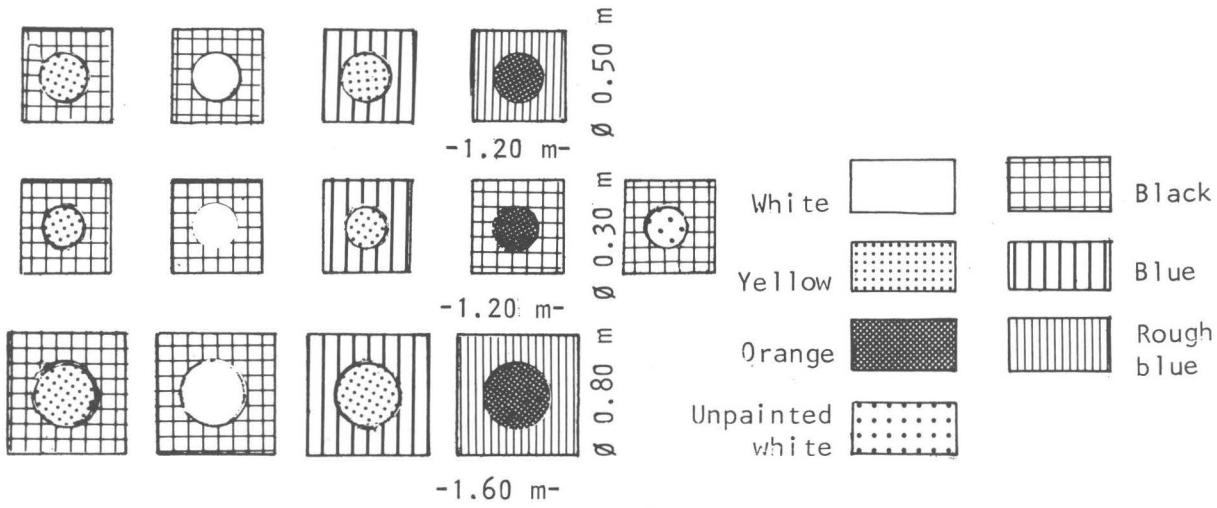


Figure 2. The colours of the targets and their placement in groups.

The test field was photographed with 2 different cameras (Table 2). With both cameras 2 flight strips were taken, one in the direction of S-N and the other in the direction of E-W with an 80% endlap at the scale 1:8000.

TABLE 2. Flight data

	Flight 1	Flight 2
Date	16.5.1979	31.5.1979
The time of day	10.45 - 11.15	14.16 - 14.36
Camera	Zeiss Oberkochen RMKA-2	Wild RC-10
Objective	Pleogon 116197	UAG II 3058
Airplane	Piper Navajo PA-31	Turbo Commander 690A
Film	Kodak Double X	Kodak Double X
Aperture	5.6	5.6
Exposure time	1/500 s	1/300 s
Filter	Yellow filter B	Yellow filter n. 525
Visibility	50 km	30 km

2. The classification

In the photography taken with the camera Zeiss Oberkochen RMKA-2 (Flight 1) the targets were classified as to their visibility by 3 observers. The range of classification was from 0 to 4. The rank of 0 was given, when the target could not be seen at all, and the rank of 4, when the target was seen

sharply, i.e. when its edges were seen sharply against the contrast sheet. Every observer classified once every target on every image. The classifications were performed with the Zeiss Oberkochen monocomparator PK-1 and the stereocomparator PSK-1 of the HUT and with the Zeiss Oberkochen stereocomparator PSK-1 of the NBS. The optical enlargement was 12. In total, about 3000 observations of visibility were made of flight 1.

In the 2nd photography taken with the camera Wild RC-10 (Flight 2), the targets were classified as to their visibility only once with a stereocomparator PSK-1. The range of classification was the same as for the first flight. There were about 1400 observations of visibility of the 2nd flight.

The photo was divided into 9 squares of equal size, and the coordinates of each target fixed it into its proper square.

7	8	9
4	5	6
1	2	3

Figure 3. The division of the image into squares.

3. Statistical analysis of the observations

3.1 In general

In the statistical study of the observations analysis of variance and simultaneous test methods have been used. The variables of the analysis of variance have been the flight direction, the position of targets in the terrain, the size and colour of the target, and the position on the image. To locate the differences between groups the multiple comparisons procedure of Scheffe and Tukey was used, conf.interval 99%. The material of this study has been handled in two sets, both flights separately.

3.2 Analysis of variance

The 1-way analysis of variance, which was used in the comparison of the flights, showed that there was a highly significant difference between them. The results of the analysis of variance are given in Table 3, where the symbols of the variables are as follows:

A = flight direction
B = position on the field
C = target size
D = target and contrast colours
E = position on the image

TABLE 3. The significant main effects and interactions

	Flight 1	Flight 2
A	**	**
B	***	-
C	***	***
D	***	***
E	***	***
AB	**	-
AC	***	-
AE	***	**
BC	**	**
BD	***	-
BE	***	***
CD	**	-
CE	***	**
DE	***	-
BCE	***	-
BDE	***	-
main effects	***	***
2-ways	***	***
3-ways	**	-
4-ways	-	-

** significant, 95 - 99%
*** highly significant, 99 - 99,9%

3.3 Simultaneous test methods

The visibility of the targets has been studied by computing the mean values of the groups in different parts of the photo. When considering two flight directions and 80% endlap, each group appears in 5 squares (Fig. 4 and 5).

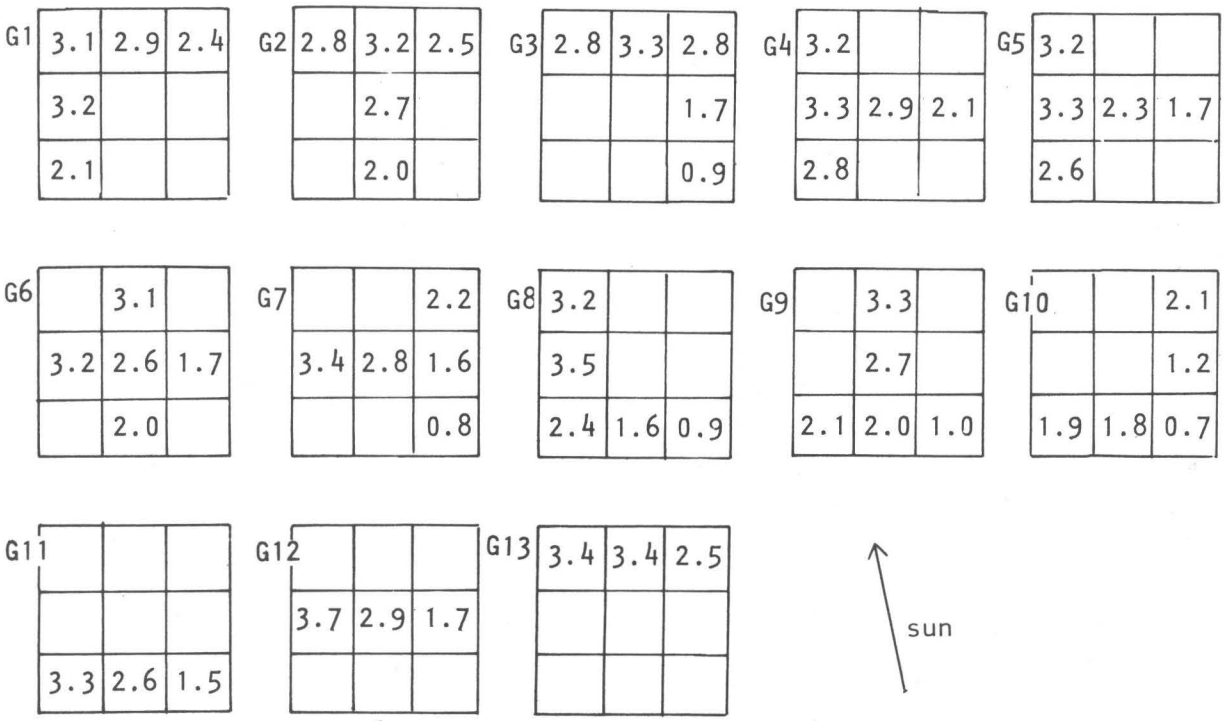


Figure 4. The average visibility of the groups in the different squares of the photo, range 0-4, flight 1.

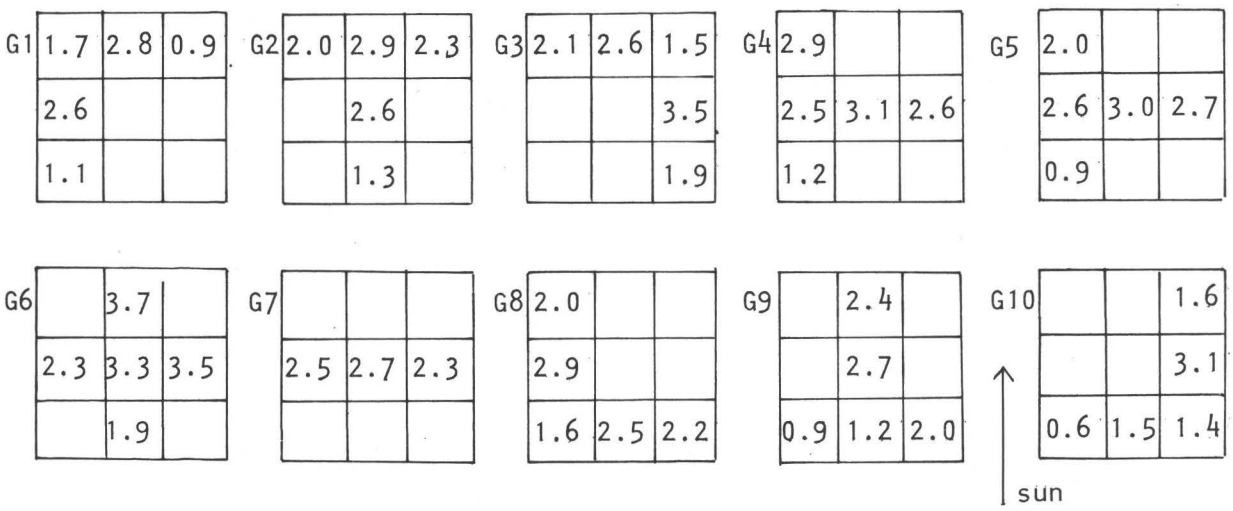
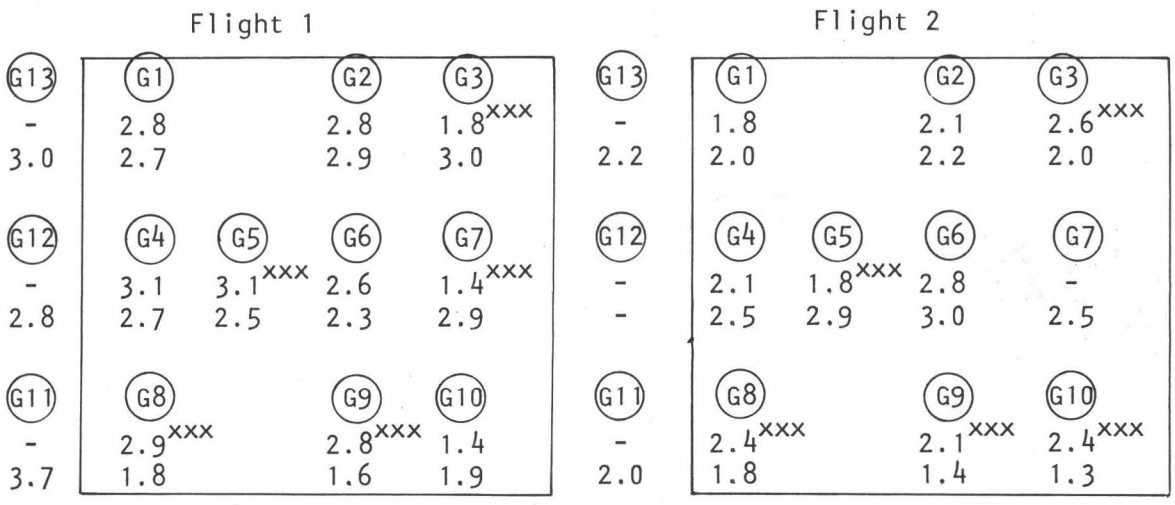


Figure 5. The average visibility of the groups in the different squares of the photo, range 0-4, flight 2.

In the following the results of the simultaneous test methods are given in the order of the variables affecting the visibility of targets.

3.31 Flight direction

When testing the effect of the flight direction on the visibility of targets, it was observed that the results differed significantly from each other. In the figure 6 the visibilities of the groups in both flight directions are shown.



Upper line - mean of the flight direction S - N

Lower line - mean of the flight direction E - W

Figure 6. The visibilities of the groups in both flight directions.

3.32 Position of the targets in the terrain

The comparison groups 11, 12 and 13 outside the test field (mean 2.9) differed very significantly from the groups on the test field (mean 2.4).

In the flight 1 the average visibility of the group 13 was the best (mean 3.0) and of the group 10 the poorest (mean 2.4).

In the flight 2 the average visibility of the group 6 was the best (mean 2.9) and of the group 10 the poorest (mean 1.8)

3.33 Size of the target

The mean values of the visibilities of the targets of different sizes are presented in Table 4.

TABLE 4. Mean values and significance of the visibilities of the targets of different sizes.

Size	Flight 1	Flight 2
0,30	2,3***	1,9***
0,50	2,6	2,2
0,80	2,7***	2,5***

3.34 Colour of the target

The effect of the colour was examined using different target-contrast sheet combinations (Table 5).

TABLE 5. Mean values and significance of the visibilities of the targets with different colour combinations.

	Flight 1	Flight 2
Yellow/black	2,8***	2,2
White/black	2,6	2,4*
Yellow/blue	2,3***	2,1
Orange/black	2,4	2,1
Unpainted white/ black	1,8***	1,6**
Yellow/rough blue	2,3	2,1

3.35 Position of the group on the image

The visibility of targets was examined determining for each square the mean of all groups located with in it (Fig.7).

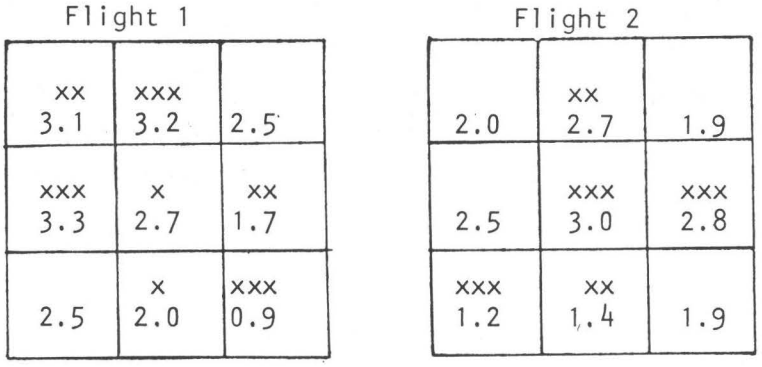


Figure 7. Mean values and significance of the visibility of the targets according to their positions on the image.

4. Conclusion

When reviewing the results, it is obvious that the 1st and the 2nd flight differ significantly from each other, mostly as to the average visibilities of groups in different squares of the image. The reason for this lies probably in different flight conditions: different airplanes, more than two weeks between the dates, and different times of day.

In the 1st flight (Fig.4), the best visibilities of groups are not usually in the middle squares, as one might presume, but on the front side of the image with regard to the flight direction. That, as well as the poor average visibility of groups on the back side of the image, hardly results from the optics of the camera, because Hakkarainen in his study /5/ has confirmed that the resolution of the camera in question RMKA-2 is excellent all over the image, nor does it result from the terrain, because the phenomenon appears in every group. One probable reason might be the turbulance produced by the airplane. Among others, Ziemann /6/ has confirmed that the effect of turbulance can be very significant for the quality of the image.

In flight 2 (Fig.5), the best average visibilities of groups are usually in the middle squares with regard to the flight direction.

The direction of the sunlight is a very significant factor for the visibility of the target in both flights. On the side of the image facing the sun, targets can be noticed to show more poorly than the other targets (Fig.6).

The effects of the terrain impairing the visibility of targets seem to be caused by shadowing trees and vertical air currents. The presumption is supported by the fact that in the groups outside the test field the visibility was significantly better.

The size of the target has a very significant effect on the visibility of targets. Larger size improves the visibility especially when other factors are impairing it (Table 4).

Colour has a significant effect on visibility. In the 1st flight, the colour combination yellow/black was significantly better than the others (Table 5). In the 2nd flight, the colours yellow/black, white/black, and orange/black were equally good. Only the colour unpainted white/black proved to be poorer than the others in both flights.

The blue contrast colour should have been considerably darker than the used one so that the results might have been congruent with other tests made earlier /3/, /4/. The roughness of the contrast colour did not improve the visibility.

On the whole, the test showed clearly that the enlargement of the target size and the choice of the colours yellow/black, white/black significantly improve the visibility of the target. Thus the visibility of the target can be ensured in unfavourable conditions.

As to the total expenses of mapping, increasing the costs of targetting material does not cause an essential rise especially when considering that plotting is facilitated and accelerated and that the pointing accuracy is improved.

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