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Metric Tests of Color Photography

Tests resulted from a joint effort of several mapping agencies under the auspices of the American Society of Photogrammetry.

(*Abstract on next page*)

Advancements in color technology are continually providing improved emulsions and film bases. These advancements have increased the confidence in color materials and stimulated an interest in the use of color aerial photography as a direct photogrammetric mapping medium, rather than merely as a support material. The benefit of color in the interpretation of aerial photographs cannot be denied. Therefore, it would certainly be uneconomical to use black-and-white photography to provide positional accuracy, and color photography to provide accuracy in interpretation, if color photography alone could fulfill both requirements.

At the Army Map Service (AMS), the task was undertaken to resolve whether color aerial photography can be used to produce topographic maps without a degradation of reliability. Comparative tests were made to determine the precision and accuracy of black-and-white film and various types of color film.

These tests came about as part of a joint effort conducted under the auspices of the American Society of Photogrammetry Committee on Color Photography.

In June and July of 1966, the Air Force flew several photographic missions over the Phoenix, Arizona, Test Area in an RC-130 aircraft. The photography used in our metric tests was taken with two Wild RC-8 cameras. As the number of film types to be tested was more than the number of cameras used, simultaneous photography, of course, could not be procured. All photography used in the AMS tests was obtained during approximately the same hours on two consecutive days under similar weather conditions.

Prior to the flights, existing horizontal and vertical ground control points were paneled to aid in their identification on the aerial photography. The distance between the control points was about one mile in both cardinal directions.

Missions were flown from south to north at 10,000-, 20,000- and 30,000-foot altitudes. Photographs were taken using one type of black-and-white film and three types of color film. One of these types of color photography was flown on two different days with two different apertures. It was also processed by two different agencies; therefore, for our testing

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purposes these were treated as two different film types.

THE TEST MATERIALS furnished to AMS consisted of positive photographic plates. Stereoscopic pairs were selected to provide four models for each film type at the 10,000-foot altitude, two models at 20,000 feet and one model at 30,000 feet. The instruments used for measuring the plates were the Zeiss PSK Stereocomparator and the Zeiss C-8 Stereoplanigraph.

Each of the paneled control points was measured 10 times in each model. This number of measurements was chosen to provide enough data for sound statistical analyses. The measured data were recorded on punch cards and statistical analysis was performed by computer on the measurements of each model.

ABSTRACT: *The metric qualities of color aerial photography compare favorably with black-and-white aerial photography. Tests were conducted on a Zeiss PSK Stereocomparator and a Zeiss C-8 Stereoplanigraph. The measurement results are evaluated and presented in tabular form for comparison. The tests indicate that all of the types of color aerial photography tested are suitable for photogrammetric mapping.*

For each point, we computed the standard deviation to determine the spread of the error distribution about the arithmetic mean of the measurements. We also computed the maximum deviations which indicate that there is a 99.9+ percent certainty that the error of any single measurement will fall between ± 3.3 times the standard deviation. Measurements exceeding this range were rejected as blunders.

Circular standard errors (CSE) were computed from the linear standard errors in order to determine the precision with which repeated readings were made in each model. This was done for data from both instruments.

WE FOUND THAT precision increased for the control points by approximately 0.5 to 1.0 micron per 10,000-foot increase in flight altitude. This was due to the ability of the operators to position better the measuring marks of their respective instruments as the size of the target image decreased. Also measured were supplementary points chosen on the black-and-white photography by the Stereocomparator operator. These same points were used for each type of film throughout the tests. Precision decreased at higher altitudes on the supplementary points due to obscuring of points which appeared to be prominent at lower altitudes.

The circular standard errors for the Comparator data on the black-and-white photography were approximately 7 microns, and for the Planigraph data 26 microns.

Table 1 shows the precision of the various color types when compared to black-and-white film. The circular standard errors of black-and-white film have been set equal to zero and the circular standard errors of the color types were adjusted accordingly. The minus signs indicate greater precision and the plus signs less precision. Color types 2a and 2b are generally more precise than black-and-white film whereas color types 3 and 4 are generally less precise.

After the statistical analyses were completed, it was necessary to reduce the instrument coordinates to ground coordinates to determine the accuracy of the measurements. The AMS version of the Schmid Single Model Analytical Reduction program was used to reduce the Stereocomparator data. Horizontal and vertical strip adjustments were used for the Stereoplanigraph data.

Plate residuals were computed for each of the control points on the Comparator data, and ground residuals were computed for data from both instruments. Root mean square errors (RMSE) were then computed for all of the points in each model.

Based on the plate residuals, the 20,000-foot altitude photography tended to be more accurate than the 30,000-foot altitude photography by 1.0 to 2.0 microns.

Table 2 shows the accuracies of the color film types when compared to the black-and-white film using the Stereoplanigraph data. The data for black-and-white film was again set equal to zero.

The Planigraph data indicated that at both 20,000 and 30,000 feet, black-and-white film was more accurate than the color types, but in general by no more than one-half meter.

TABLE 1. CIRCULAR STANDARD ERRORS OF COLOR FILM AS RELATED TO BLACK AND WHITE FILM (MICRONS)

Type	*Altitude*			*Aver. Models*	*Altitude*		*Aver. Models*
	30,000	*20,000*	*10,000*		*30,000*	*20,000*	
	Stereocomparator Data				*Stereoplanigraph Data*		
Control Points							
2a	−1	0	0	−1	−2	0	−1
2b	0	0	−1	−1	−2	−2	−2
3	+3	0	+1	+1	0	0	0
4	+1	0	+2	+1	−1	−1	−1
Supplementary Points							
2a	−3	0	+1	0	+2	−1	−3
2b	−1	−2	+2	0	+1	−2	−3
3	+4	+3	+3	+2	+5	+2	+2
4	+5	0	+5	+2	+3	+2	+2
All Points							
2a	−2	0	0	+1	−1	0	−1
2b	−1	−2	0	0	−2	−2	−2
3	+3	0	+2	+2	0	0	0
4	+1	0	+4	+3	0	0	0

Table 3 shows the accuracies obtained for the Stereocomparator data. The ground residuals show that color types 2a and 2b were more accurate by about 0.1 to 0.2 of a meter at 30,000 feet, and 0.3 to 0.4 of a meter at 20,000 feet. Types 3 and 4 were less accurate at 30,000 feet by less than 0.2 of a meter. At 20,000 feet these two types tended to be more accurate than black-and-white film by about the same amount.

THROUGHOUT THE TESTS, the data from the Comparator had a greater consistency than that from the Planigraph; therefore, I believe that more reliance can be placed on the Comparator measurements. However, there was no great discrepancy between the overall results obtained from both instruments.

The tests performed show that the aerial color film tested can be used to obtain precision and accuracy approaching or surpassing black-and-white aerial film.

As an additional test, densitometer readings were taken on the same points of each of the film types. It was found that there seems to be a relation between the precision and accuracy readings and the density of the plates.

The densest plates (approximately 1.00 Diffuse Transmission Density Units), produced the more precise and accurate results, whereas the least-dense plates (approximately 0.24 Density Units), gave less precision and accuracy. This leads us to believe that, had the densities of all the film types been the same, the results obtained for the various film types would have been nearly identical. This seems to indicate that quality standards must be carefully investigated before color photography is put into general use.

TABLE 2. COMPARISON OF COLOR FILM RMSE AND CSE TO BLACK AND WHITE FILM RMSE AND CSE (C-8 DATA)

Altitude (feet)	*Type Color*	*Ground (meters)*			
		RMS			*CSE*
		X	*Y*	*Z*	*XYZ*
30,000	2a	−0.08	+0.01	+0.63	+0.44
	2b	−0.28	+0.01	+0.05	−0.11
	3	+0.49	0.00	+0.56	+0.68
	4	+0.02	+0.61	+0.59	+0.73
20,000 Averaged	2a	−0.09	+0.28	+0.06	+0.14
	2b	+0.05	+0.32	−0.06	+0.17
	3	0.00	+0.25	+0.27	+0.30
	4	+0.05	+0.70	+0.80	+0.36

TABLE 3. RELATION OF COLOR FILM RMSE TO BLACK AND WHITE FILM RMSE (STEREOCOMPARATOR)

Altitude (feet)	*Type Color*	*Plate (Microns)*			*Ground (Meters)*			
		X	*Y*	*XY*	*X*	*Y*	*Z*	*XYZ*
30,000	2a	−1	−2	−1	−0.17	−0.27	+0.09	−0.09
	2b	−3	−4	−3	−0.29	−0.41	−0.15	−0.27
	3	+1	+1	+2	+0.11	−0.13	+0.11	+0.03
	4	+2	+2	+3	+0.17	+0.19	+0.17	+0.17
20,000 Averaged	2a	−4	−6	−4	+0.08	−0.13	−0.42	−0.33
	2b	−5	−7	−5	−0.02	−0.24	−0.46	−0.40
	3	0	−4	0	+0.31	+0.23	−0.08	−0.02
	4	−1	0	0	+0.04	−0.13	−0.21	−0.18

VARIOUS POINTS to be considered have suggested themselves during these tests and the following recommendations are proposed for future tests:

- A geodetically controlled area of varying terrain types and ground cover should be selected, since this would be more representative of terrain encountered in normal production.
- The paneled points used in the Phoenix area were most helpful in point identification but they produced an ideal situation that is likely never to be equaled in usual mapping missions. It would, therefore, be more realistic to restrict testing to the type of photo-identifiable point generally used.
- To decrease the variables introduced by the lack of simultaneous photography, the small four-camera system for multi-emulsion studies discussed by Dr. Marlar and Dr. Rinker in the November 1967 issue of *Photogrammetric Engineering* should be considered for use.
- Processing of the films should be rigidly controlled to insure uniform quality.
- The 10,000-foot altitude photography did not cover a large enough ground area, and should not be used for accuracy testing unless half- or quarter-mile control nets exist.
- Tests should possibly be performed to determine whether our findings hold for ultra-high altitudes and, if not, to determine the extent of degradation.

IN CONCLUSION, while additional or different tests performed at the AMS or other governmental or civilian agencies might produce different results in ranking of film types and magnitude of residual errors, it is believed that the conclusions will be essentially the same; that is, that the color film types tested can be used, for all practical purposes, with the same confidence as black-and-white film. Whether the cost of color photography is warranted for a particular photographic mission must be determined by the user.