OEEPE TEST ON ORTHOPHOTO AND STEREO-ORTHOPHOTO ACCURACY

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A B S T R A C T

A test has been conducted by OEEPE which aimed at obtaining information on the impact of five main parameters on the metrical accuracy of typical orthophotos and stereo-orthophotographs. These parameters consist of the scale of the aerial survey to rectify, that of the survey from which the D.T.M is derived, that of the orthophoto, the slit width and the scanning direction.

Three scales were considered for aerial surveys and D.T.Ms(1:60 K, 1:30 K and 1:16 K-scale) and two for output products (1:25 K and 1:5 K-scale).

R E S U M E

L'OEEPE a effectué un essai visant à étudier l'influence de cinq facteurs essentiels sur la précision métrique des orthophotos et stéréo- orthophotographies.

Il s'agit de l'échelle du levé aérien à orthophotographier, de celle du levé dont on a tiré le M.N.T, de l'échelle de l'orthophoto de la longueur de la fente et du sens de balayage.

On a pris en compte trois échelles pour les levés aériens et les M.N.T (1 : 60 K et 1 : 30 K et 1 : 16 K) et deux échelles pour les produits en sortie (1 : 25 K et 1 : 5 K).

Key Words : Accuracy Altimetry DEM Mapping Orthophoto Stereoscopic 3-D

PROJECT DESCRIPTION

TEST AREA

The test area is located in France, in the Massif Central area, around the small town of Lacapelle Marival (Lot "département") consisting of 1200 people.
It has a wide range of relief from 350 m up to 628 m above datum, including valleys as deep as 150 m near its sides and slopes ranging from moderate (some 30 % slopes in the middle) to steep (many 50 % to 60 % slopes on the hillsides).
The terrain is gently rolling in the middle of the area.

Due to the neighbourhood of the "Causse de Gramat" the forest is not very thick, while many natural features are disseminated over the entire test area, which is portrayed on the basic map at 1 : 25 K-scale with a 10 m contour interval.
The test area covered a full frame at 1:30 K-scale and had a wide range of relief and slopes. It was fitted with as many as 271 fixed points, including 170 natural features and 101 signalised points, suited to 1:16 K and 1:30 K-scale surveys.
The accuracy of these points can be inferred from the origin of their determination and from some redundancy in their measurements. Their accuracy is ranging from about 20 cm to 40 cm .

Considering the present trend in the national mapping agencies to establish heighting databases at medium scale by digitising contours of base map series at 1 : 25 K-scale or by stereo-plotting pairs at 1 : 30 K-scale and storing the related data in a vector format, it was decided to deliver to each producing center the required altimetric data in a format consisting of contours stored on magnetic tape directly.

Each operative center was responsible for computing the profiles required for rectifying aerial photographs into the ortho and stereo-orthophotos it has agreed to do, using its own algorithms to interpolate the relevant data from the contours.

PRODUCTS

The test was conducted by IGN (F) acting as pilot center (but also as operative and assessing center). Seven producing centers delivered a total number of 90 products, out of which 59 were assessed, analyzed and retained for their results, comprising 29 orthophotos and 30 stereomates.

A special mention should be made of some agencies for their prominent participation which permitted to draw efficient and numerous comparisons of products; among them I would like to quote, (see LIST OF OPERATIVE CENTERS):

. GID (DK), IGM (I), IGN (F), IPUS (D), ITPT (I) for preparation of control, check points and contours.

. IFAG (D), IGN (F), ITC (NL), for production of the major part of the required ortho and stereo-orthophotos, as well as NBS (SF), NLS (S) and the Wild Company (WH) for the useful complementary products they delivered.

. IGN (F), IPTU (A) for carrying out the major part of the measurements; NRC(CDN) and UCL (GB), for the additional part they were able to take regarding measurements.

. IGN (F) and its school (E.N.S.G) that fostered completion of the test, so that full results could be obtained from these measurements and conclusions fully drawn.

Five centers produced ortho and stereo-orthophotographs using a WILD-OR 1 (IGN (F), ITC (NL), NB S (SF), NLS (S) and WH (CH)) and a sixth center used a Zeiss- Z 2 (IFAG (D)).

MEASUREMENTS

Six instruments were used for measurements onto the products delivered to the four assessing centers, as follows :

- i) IGN (F) used the ORTOSTER, a home made prototype, fitted with encoders, storing data on tapes. This ORTOSTER accepts a large format of size 330 x 570 mm, and has resolutions of 2 cmm in x, y and 1 cmm in px, free hand motion, and fine-adjustement track-ball devices.

- ii) IPTU (A) used a STEREOGRAPH, from R and A.ROST C^y (Wien,(A)) fitted with Diadur glass scale of 1 cmm resolution, storing data on tapes. The STEREOGRAPH accepts a very large format of size up to 550 x 750 mm, has a free hand motion and fine adjustment screws.

- iii) NRC (CDN) used its STEREOCOMPILER, built in its laboratories, which was specifically designed to accomodate stereo-orthophotos and had been in use for about twelve years for research purposes.
  This instrument accepts a very large format of size up to 400 x 720 mm, has resolutions of 1 cmm but did not store data on tape, while delivering x, y and px listings; it has a free hand motion device with air bearings and a px micrometer.

- iiii) UCL (GB) used three types of instruments :
  . a CP1 stereoplotter modified to plot from stereo-orthophotos, which accepts small formats of size 250 x 250 mm; it has a free hand motion device and a px measurement by footwheel.
  . a KERN DSR1 analytical stereoplotter accepting a small format of 250 x 250 mm and storing very accurate data on a floppy disc.
  . a ROSS stereo-orthophoto plotter developped by ROSS Instruments Ltd., and commissioned by the OS (GB). The prototype was made available to UCL (GB). It accepts a large format of size 400 x 400 mm and has a free hand motion device, a tracker ball and a joystick for px removal, (ALI, J and I.J. DOWMAN).

Eight combinations of stereo-orthophoto printers and compilers were thus obtained.

Each product or arrangement of products has been measured by two rounds, sometimes three rounds, each of them including closure measurements on GCPs.

Three classes of format can be noted consisting of products the size and number of which are as follows :

- class 1, small format : products at an output scale of 1:25 K of size either 22 x 26 cm (full frame) or 12 x 26 cm (stereopair amounting to nineteen products
- class 2, medium format : products at an output scale of 1:5 K, coming from photographs at 1:16 K-scale, of size about 30-35 cm by about 50-65 cm, amounting to sixteen products
- class 3, large format : products at an output scale of 1:5 K, issuing from photographs at 1:30 K-scale, of size about 55-65 cm by 75-90 cm, amounting to twenty four products.

The actual number of pointings which have been carried out is as follows :

IGN (F)	:	3120
IPTU (A)	:	1752
NRC (CDN)	:	276
UCL (GB)	:	509
Total number of pointings	:	5657

This total number includes pointings carried out for determining the pointing precision, and is thereby more that twice as much as the number of averaged measurements (2243), used as inputs in the further computations for assessing planimetric and altimetric accuracies

PLANIMETRIC ASSESSMENT

PLANE TRANSFORMATIONS : FOUR ASSESSING METHODS

As described hereafter, different plane transformations have been computed and applied to those measurements, achieving a conversion of the orthophotos co-ordinates and enabling a comparison with those from the general catalog, established in the IGN (F) Lambert grid system.

Once these transformations performed, some residuals appeared excessive, requiring a cancelling procedure for eliminating such measurements to be considered as gross errors. It was decided to eliminate those measurements exceeding 2.58 times the value of the r.m.s.e. in any residual, which corresponds to the maximum error with a 1 % confidence level to be reached. Seven iterative cycles were necessary for stabilizing the procedure, no extra measurement having to be rejected after this last computation. The number of cancels was limited to 230, namely 10 %.

For that purpose, four methods have been set up, comparatively used and applied to most of the orthophotographs. They consisted of three similarities and one affinity, the effects of which were therefore those of translations, rotations and scaling either similar along x and y or different. Hence they permitted it to evaluate the accuracy of the different products by computing residuals, standard deviations and r.m.s.e, on GCPs and check points as well, first for each round then for each orthophoto as an average of the related rounds, weighted according to the number of points in the round.

A first similarity has been computed by using only two remote known points. These base points were chosen by a computer program as being those displaying the largest distance between them in the round, in a similar way as a user should have operated.

It was stated once more that extrapolation outside a base acting as a control point line, should not take place, which every user should be aware of, when scaling his orthophoto.

The second approach which was practised to convert orthophoto coordinates into ground coordinates is a well-known one and consists of a similarity based upon the whole GCPs, namely points used as GCPs when producing the orthophotos.

The improvement of accuracy of the second transformation reaches 11 % on average on check points.

It is therefore efficient to use more than two points, for example five or six, in the determination of the similarity.

In the next step, the question of whether scale variations could not occur between the x and y directions of the orthophotos, was considered. Hence an affinity based on GCPs replaced the above mentionned similarity.

From 14 orthophotos,it may be seen thatapplying an affine transformation instead of a similarity does not appear worthwile.

In the fourth and last step, the similarity was computed by using the whole points available, both control and check points. As a result, this fourth assessing method produces superior results to any previous method, increasing by 21 % the accuracy obtained; however, it requires much more control points for the similarity.

These results permit it to determine the extent to which a better accuracy can be obtained for both GCPs and check points when using a given orthophoto, by an increase of the number of points used as control points for the plane-transformation of coordinates. It could be recommended to use up to twelve or fifteen such control points, which provides an improvement of 20 % to 25 % on both GCPs and check points.

The accuracy at GCPs used in orthophoto production is better, by 20 % to 50 %.

As a conclusion, scaling the orthophoto onto the orthophotoprinter was generally quite satisfactory, though it is recommended to check the actual scale of the product when accurate improvements are required, at least by using two distant control points for clearing any possible film shrinkage.

ALTIMETRIC ASSESSMENT

TWO ASSESSING METHODS

Two methods aimed at computing elevations as function of parallaxes were always determined from the measurements themselves: the first one, based on two points displaying the largest elevation difference, the second one, based on the whole fixed points available in each stereo-orthophoto pair (GCPs and check points).

The second one delivers better results by 21 % on the average.

This improvement comes not only from a reduction of the resulting error when using an average on several points, but from removing by a least-squares adjustment a possible rotation between the stereomate and the orthophoto when setting up the pair onto the carriages of the measurement device.

Profiling in x provides better heighting results because differences between the profiles actually used for creating the orthophoto and the stereomate are larger when profiling in the y direction, causing worse altimetric parallaxes, as expected and noted,(see DUCHER, G. Jul 1980 and Dr. K. KRAUS ,1978).

GENERAL RESULTS

Targetted points were found to have an improved accuracy by up to 35 % in planimetry and 40 % in altimetry. Emphasis has thus to be laid on the importance of point identification, interpretability of detail, easiness of pointing.

Near-nadir points benefit from improvements in accuracy of 21 % in planimetry and 31 % in height, while points near to corners are conversely degraded, but only by 5 %; as a result the nadir-half of a pair is 8 % better than the other one, so that it should be recommended to rectify the whole nadir area of each photograph, especially when blocks of several strips have to be rectified.

Neighbouring points display great improvements as regards their relative accuracy, reaching 27 % in planimetric differences and 44 % in elevation differences. Such a high homogeneity makes stereo-orthophotos best suited to map revision and civil engineering projects.

The whole improvements have a cumulative effect at points which own several properties and benefit from an addition of improvements, such as e-g targetted GCPs, near-nadir targetted points, or near-nadir neighbouring points.

The value of the D.T.M actually used in the rectification stage has been approached by assessing orthophoto-pairs from both frames of an aerial pair. The heighting accuracy achievable from stereo-orthophotos is generaly better than that of the original D.T.M, by a factor ranging from 0.8 to 3.4 times, and amounts to 3.7 x H/10 000 on the average (H being the altitude of the rectified survey).

Some absolute results show that high levels of accuracy can be reached, such as those displaying at natural points a r.m.s.e of 50 microns, resultant vector in x,y at photo scale,or of 1.3 x H/10 000 in height. It was demonstrated that off-line differential rectification of an aerial pair at 1:16 K-scale into a stereo-orthophoto pair at 1:5 K-scale, using a D.T.M derived from aerial surveys at 1:60 K-scale could ultimately provide as good an accuracy as 0.60 m (r.m.s.e) in height at targetted points (i.e 2.5 x H/10 000), 0.90 m (r.m.s.e) for x,y resultant vector, also at targetted points (i.e 56 microns at photo scale).
But large discrepancies are noted between absolute results, as a function of the input parameters, since many products resulted from an off-limit use of small-scale data, as the test was also specially designed to get a better acquaintance with the impact of scale parameters, over a wide range.

Discrepancies resulted also from the assessing method, showing variations of up to 30 % in results. Discrepancies were finally noted between similar products from the same center, showing that it is not so easy a task to reach the top level permitted by the data quality.

PRATICAL FORMULAE

However general formulae have been established, involving only scales of input, DTM and output data, disregarding the slit width which did not appear very significant in this test.

Though approximate, they can be used as guidelines to choose the most efficient and cost-saving scales complying with a required accuracy for the orthophoto; (two-thirds of the orthophotos carried out using similar parameters, have a r.m.s.e error differing from the e value computed by these formulae, by less than ± 20 % in planimetry and ± 35 % in height).

They apply to products carried out in the conditions of the test.

Among those conditions are :

- standard photogrammetric aerial survey
- similar classes of relief (from 100 m to 240 m as maximum elevation differences and 40 m to 75 m for the elevation standard deviation).
- similar scale-ranges as those used in the test
- regular distributions of GCPs and check points over the entire area of the orthophoto which covers the full original frame
- good proportions of well-defined features, with accurately fixed co-ordinates, used as GCPs and check points as well. Using signalised points is highly recommended (their proportion in the test was 33 %).
- an assessing method based on a similarity using a least-squares adjustment on at least seven points, and preferably twelve or fifteen points.
- a stereo-compiler allowing a pointing standard deviation of 60 microns, resultant vector and two-round measurements.

A slit width of 4 mm or 5 mm is recommended,but a 8 mm slit can also provides similar results.

Those general formulae are expressed as follows :

$$e_{xy}^2 = 0.75 \times \left(\frac{\text{PHOTO}}{15\ 000}\right)^2 + 0.20 \times \left(\frac{\text{DTM}}{15\ 000}\right)^2 + 0.25 \left(\frac{\text{ORTHO}}{5\ 000}\right)^2$$

$$e_{z_x}^2 = 0.30 \times\left(\frac{\text{PHOTO}}{15\ 000}\right)^2 + 0.10 \times \left(\frac{\text{DTM}}{15\ 000}\right)^2 + 0.25 \left(\frac{\text{ORTHO}}{5\ 000}\right)^2$$

$$e_{z_y}^2 = 0.30 \times\left(\frac{\text{PHOTO}}{15\ 000}\right)^2 + 0.50 \times \left(\frac{\text{DTM}}{15\ 000}\right)^2 + 0.25 \left(\frac{\text{ORTHO}}{5\ 000}\right)^2$$

in which :

e_{xy} = r.m.s.e in planimetry (resultant vector) in meters, on the ground, on natural points (including some targetted points), of the resulting orthophoto, off-line scanned in whatever x or y direction .

e_{z_x} , e_{z_y} = r.m.s.e in height, in meters, on the ground, on natural points (including some targetted points) of stereo-orthophoto-pairs off-line scanned resp. in the x and y directions.

PHOTO = 1 : scale of the aerial survey (ranging from 16 K to 60 K) to be rectified.

DTM = 1 : scale of the DTM, i-e of the survey which was plotted into contours and gave rise to the DTM, (ranging from 16 K to 60 K).

ORTHO = 1 : scale of the orthophoto and stereo-orthophoto (ranging from 5 K to 25 K).

The scale ranges within which these formulae are applicable, can be somewhat extended towards both larger and smaller scales, as shown by some examples merging data from space and aerial surveys (see table 1, ex n° 11., 12 and 13), to obtain orthophotos at medium to large scale (1 : 10 K to 1 : 25 K), using aerial photographs at 1 : 30 K and 1 : 60 K-scale and D.T.M derived from SPOT data and/or, in the future, from new space projects at 5 m. pixel size, currently being developed by NASA, ESA or CNES, (see table 1).

CONCLUSIONS

As a result, when deriving the D.T.M from the same survey as that to be orthophotoprinted, enlargements of up to 4.5 or 5.0 times are allowed for the orthophoto, while complying with well established map accuracy standards, (see table 2).
Conversely, each time a D.T.M from a scale smaller than that of the survey to rectify is available, it is strongly recommended to use this one, since it could be more cost-saving. Examples are given showing that a D.T.M derived from a scale smaller than that of the survey to rectify by a factor of 2, 3 or 4 times, allows enlargements of as much as resp. 3.5 times, 3.0 or 2.3 times for the orthophoto,(see"example of Individual form"andtables).

Existing height databases and/or D.T.M derived from space surveys should therefore be taken into account whenever possible, when off-line differentially rectifying a given survey.

The scale of the photograph to be rectified is the driving factor.

The scale of the DTM, namely that of the aerial photograph from which the D.T.M. is derived, has the least impact on the results.

Fully digital processing methods, which should still improve the end-product quality, will be an incentive for further developing the stereo-orthophoto technique. Appropriate tests at scales smaller and larger than those used in the present OEEPE test, could be conducted later on, in order to assess the actual possibilities evolving from CCD cameras and digital rectification.

The results obtained in this OEEPE test apply to whatever kind of data is used in input, in analog or digital format, either from field, aerial or space survey; these results are independant of the technology used in production, whatever type of off-line orthophoto-printer is used,optical or digital.

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APPENDICES

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LIST OF OPERATIVE CENTERS

ACRONYMS	NAMES
GID (DK)	Geodaetic Institut of Denmark-Copenhaguen (Denmark)
IFAG (D)	Institut für angewandte Geodäsie (Federal Republic of Germany)
IGM (I)	Istituto geografico militare - Firenze (Italy)
IGN (F)	Institut géographique national - Paris (France)
IPTU (A)	Institut für Photogrammetrie, der Technischen Universität Wien-Vienna (Austria)
IPUS (D)	Institut für Photogrammetrie der Universität Stuttgart (F.R. Germany)

ACRONYMS	NAMES
ITC (NL)	International Institut for Aerial Survey and Earth Science-Enschede (The Netherlands)
ITPT (I)	Istituto di Topografia del Politecnico Torino (Italy)
NBS (SF)	National Board of Survey - Helsinki (Finland)
NLS (S)	National Land Survey - Gävle (Sweden)
NRC (CDN)	National Research Council - Ottawa (Canada)
UCL (GB)	University college London (U.K.)
WH (CH)	Wild-Heerbrugg Company (Switzerland)

TABLES

for [1] [2] [3] [4], see REFERENCES.

EX. N°	1:SCALE OF THE AERIAL OR SPACE SURVEY (INPUT)	1:SCALE OF THE D.T.M.	1:SCALE OF THE ORTHO-PHOTO (OUTPUT)	COMPUTED PLANIMETRIC R.M.S.E. (resultant vector) AT GROUND SCALE (in meters)	COMPUTED PLANIMETRIC R.M.S.E. (resultant vector) AT ORTHO-PHOTO SCALE (in mm)	WITHIN US N.M.A.S. (90% <0.5 mm)	COMMENTS
1	1000 K (SOYUZ KATE--200)	200 K (?) 50 K (?)	200 K 1000 K	68 m 115 m	0.33 mm 0.12 mm	no yes	- Hungarian test reporting accuracy of 0.25 mm, see [1] - digital hungarian test, r.m.s.e. obtained 0.1 mm
2	820 K SPACELAB-MC	820 K	100 K	54 m	0.54 mm	no	- see [3] ESA test: accuracy 0.25 mm over 1/20 of a photo
3	730 K US-LFC	730 K	100 K	48 m	0.48 mm	no	
4	300 K SPOT	150 K (B/H=1)	50 K	185 m	0.37 mm	no	- see [4] r.m.s.e range obtained 0.25-0.38 mm in stereoplotting.
5	220 K SOYUZ-KFA-1000	220 K 50 K	50 K 50 K	15 m 13 m	0.30 mm 0.25 mm	yes yes	- see [2] Hungarian test reporting accuracy of 0.2 mm
6	175 K STEREO-MOMS	150 K 150 K	50 K 25 K	12 m 11 m	0.24 mm 0.45 mm	yes no	
7	175 K NEW SPACE PROJECT AT 5 m PIXEL SIZE	100 K 100 K (B/H=1)	50 K 35 K	12 m 11 m	0.23 mm 0.32 mm	yes yes	- would be very efficient
8	150 K AERIAL PHOTO	150 K 150 K 30 K	100 K 50 K 50 K	14 m 11 m 10 m	0.14 mm 0.22 mm 0.20 mm	yes yes yes	- used in Groënland (DK) - would be efficient - used in Sweden
9	120 K AERIAL PHOTO	120 K	64 K	10 m	0.15 mm	yes	- used in Alaska (USGS) (NHAP)
10	80 K AERIAL PHOTO	80 K	24 K	5.7 m	0.24 mm	yes	- used by USGS (NHAP)
11	60 K AERIAL PHOTO	150 K SPOT (B/H=1) 100 K (SPACE)	25 K 20 K	6.2 m 5.0 m	0.25 mm 0.25 mm	yes yes	- would be very efficient - would be very efficient using D.T.M. from ex. n° 7
12	50 K AERIAL PHOTO	150 K SPOT (B/H=1) 100 K (SPACE)	20 K 15 K	5,7m 4.4 m	0.28 mm 0.29 mm	yes yes	- would be very efficient. - would be very efficient using D.T.M. from ex. n° 7
13	30 K AERIAL PHOTO	100 K (SPACE)	10 K	3.6 m	0.36 mm	no	- would be a very efficient product using D.T.M. from ex. n° 7

EXAMPLES OF EXTENDED APPLICATION OF <u>general formulae</u>
TO SMALLER SCALE:
COMPUTED (AND EXPECTED) PLANIMETRIC ACCURACY OF ORTHOPHOTOS

TABLE 1.

EXAMPLE N°	1 : SCALE OF THE AERIAL SURVEY (INPUT)	1 : SCALE OF THE D.T.M.	1 : SCALE OF THE ORTHO-PHOTO (OUTPUT)	COMPUTED PLANIMETRIC R.M.S.E. (resultant vector) AT GROUND SCALE (in meter)	COMPUTED PLANIMETRIC R.M.S.E. (resultant vector) AT ORTHO-PHOTO SCALE (in mm)	WITHIN U.S. N.M.A.S. (90 % <0.5 mm)	COMMENTS
1 2	60 K 60 K	60 K 60 K	25 K 12.5 K	4.6 m 4.1 m	0.18 mm 0.32 mm	yes yes	- max. enlargement poss.
3	45 K	45 K	10 K	3.1 m	0.31 mm	yes	- max. enlargement poss.
4 5	40 K 40 K	50 K 40 K	25 K 12 K	3.7 m 2.9 m	0.15 mm 0.24 mm	yes yes	- very good for 25 K map revision;used by GID (DK) - USGS digital test
6 7 8 9 10	30 K 30 K 30 K 30 K 30 K	60 K 60 K 30 K 30 K 16 K	25 K 5 K 25 K 5 K 30 K	3.5 m 2.5 m 3.2 m 2.0 m 3.5 m	0.14 mm 0.50 mm 0.13 mm 0.40 mm 0.12 mm	yes no yes no yes	- very good for 25 K map revision - compare with ex. n° 6 - not very efficient
11	25 K	25 K	25 K	3.0 m	0.12 mm	yes	- see test for map revision, using a GPM; r.m.s.e. obtained is ranging from 0.10-0.17 mm
12	22.5 K	22.5 K	5 K	1.5 m	0.31 mm	yes	- max. enlargement poss.
13 14	22 K 22 K	40 K 22 K	12 K 12 K	2.1 m 1.9 m	0.18 mm 0.16 mm	yes yes	USGS digital test,
15 16	20 K 20 K	60 K 30 K	5 K 5 K	2.2 m 1.5 m	0.40 mm 0.31 mm	no yes	- more efficient than ex. n° 9 - very efficient for 5 K
17	16 K	16 K	6.5 K	1.2 m	0.18 mm	yes	- see SUDBURY CDN test, r.m.s.e. obtained 0.17 mm
18 19 20 21 22	15 K 15 K 15 K 15 K 15 K	60 K 50 K 30 K 30 K 15 K	5 K 5 K 5 K 4 K 5 K	2.0 m 1.8 m 1.3 m 1.3 m 1.1 m	0.40 mm 0.35 mm 0.26 mm 0.32 mm 0.22 mm	no no yes yes yes	possible use of alti-data base at 1:30 K

EXAMPLES OF APPLICATION
OF PRACTICAL FORMULA
RANGING WITHIN LIMITS OF THE OEEPE TEST
(AT MEDIUM SCALE) :
COMPUTED (AND EXPECTED) PLANIMETRIC ACCURACY
OF ORTHOPHOTOS

TABLE 2.

LIST OF ABBREVIATIONS AND ACRONYMS

C.C.D. = charge-coupled device

CNES = centre national d'études spatiales (the French space agency).

D.E.M. = digital elevation model.

D.T.M = digital terrain model (here, similar to D.E.M).

ESA = european space agency.

G.C.P. = ground control point

G.I.S = geographic information system.

G.P.M = Gestalt Photo-Mapper

H = flying height (related to the survey to rectify)

K = kilo (10^3) for example at 1 : 50 K-scale means at 1 : 50,000-scale.

M.N.T. = modèle numérique du terrain (in English D.T.M)

NASA = National Aeronautics and Space Administration (U.S.A.).

N.H.A.P. = National High Altitude Photography (U.S.A.).

N.M.A.S. = National Map Accuracy Standards (U.S.A.).

R.M.S.E. = root mean square error; it refers to the accuracy of a product assessed through n measurements and is computed as being equal to $\sqrt{\frac{\Sigma(vi^2)}{n}}$ in which vi is the true error of each measurement (measured value minus true value). The r.m.s.e is superior or equal to the standard deviation.

EXAMPLE OF INDIVIDUAL FORM FROM EACH ORTHOPHOTOGRAPH

The best quality indicator is the r.m.s.e. from the last plane-transformation, set up on the whole points. (*)

STAGE 3.12		ORTHOPHOTO N° 66					Relief : class III	
Ortho Product	Aerial Photo	1: SCALE OF Aerial Survey	1: SCALE OF D.T.M	1: SCALE OF Ortho	Slit Width	Scan dir.	Operative Center and Instrument for ortho Production	Operative Center and Instrument for ortho Assessment
n° 66	n° 3	16 K	60 K	5 K	8 mm 40 m	x	ITC (NL) - OR1 -	IPTU (A) - STEREOGRAPH -

HEIGHT ACCURACY				
In a round, number of points cancelled	In a round, number of points measured & used	Number of rounds	Total number of cancels	Total number of measurements used
13	52	1	13	52

Stereopair	Altimetric transform. set up on :	standard deviation (meter)	r. m. s. e. (in Z) accuracy (meter)	r. m. s. e. (in Z) accuracy flying height H
n° 66 -67	2 points	0.80	1.27	5.3 x H/10000
	* The <u>whole points</u> (least sq. adjust.)	0.80	<u>0.87</u>	3.6 x H/10000

PLANIMETRIC ACCURACY

Stereopair	In a round, number of points cancelled	In a round, number of points GCPs	In a round, number of points measured and used	Number of rounds	total number of cancels	total number of measurements used
n° 66 - 67	10	6	55	1	10	55

Planimetric transformation set up on :	Resultant vector in (x, y) on the ground (meter) st^d deviat precision	on the ground (meter) r.m.s.e. accuracy	at photo scale (microns) st^d deviat precision	at photo scale (microns) r.m.s.e. accuracy	at ortho scale (microns) st^d deviat precision	at ortho scale (microns) r.m.s.e. accuracy
- 2 points (similarity)	1.73	2.07	108	129	346	414
- The whole GCPs (similarity by least sq. adjust)	1.64	1.64	102	102	328	328
- The whole GCPs (affinity by least sq. adjust)	1.76	1.71	110	107	352	342
* - The <u>whole points</u> (GCPs + check pts) (similarity by least (sq. adjust)	1.62	<u>1.61</u>	101	<u>101</u>	324	<u>322</u>