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DETECTION OF UNEXPLODED BOMBS OF WORLD WAR II BY QUANTITATIVE INTERPRETATION OF RECONNAISSANCE PHOTOGRAPHS

H. Mohl, Stuttgart / H. Tauber, Münster

1. INTRODUCTION

Unexploded bombs of World War II are still nowadays - more than 40 years after the air raids - a serious danger. This is valid mainly for downtown areas where, on occation of large constructions, excavators or caterpillars are in permanent danger to touch the fuse of a bomb und to cause a sudden explosion /1/.

It is of public interest to localize these unexploded bombs and to disarm them before opening a building site.

With the release of several hundred-thousands of british reconnaissance photographs by the U.K. the German authorities and private companies are enabled to apply new methods for the systematic data acquisition and storing of the positions of bomb hits.

The objects are to be saved on a data base with their state plane coordinates and a codenumber which allows the future updating of the object's data.

So, in an planned construction area, all unexploded bombs can be plotted from the data base into an existing map or a map section. Setting out measuring elements can be added to the plotted data.

In the field the position of the object to be disarmed can be defined with an accuracy of 1 m (city areas) to 2,5 m (open field). This ist generally sufficient for the final approach by means of electro-magnetic detectors.

The following sections describe a plotting system which allows the systematic stereoscopic evaluation of reconnaissance photographs in an economic and flexible manner.

2. CHARACTERISTICS OF THE PHOTOGRAMMETRIC EVALUATION OF RECONNAISSANCE PHOTOGRAPHS

Reconnaissance images of World War II were generally taken with TELE- or SUPER-TELE-Cameras (f = 24" to f = 36") the calibration of which is either not known or unprecisely given. The image quality has suffered under the storing over decades. Only paper prints are available.

Nevertheless the hits of unexploded bombs can, after a special training, easily be distinguished from other objects of similar size or from bomb craters. The stereoscopic analysis, however, is indispensable in order to avoid misinterpretations.

Localization and disposal of bombs in the field is time consuming and expensive, so that wrong identifications should be avoided.

In the orientation process convergency problems are occasionally caused by the small image angles of tele- or supertele cameras - in this case swings and the difference of transversal tilts can numerically not be separated from eachother (ref. FIG. 1).

The main problem of the whole working process is the selection of control points and the determination of their terrain coordinates. Over the decades since the end of the War nearly nothing remained as it was saved in the reconnaissance photographs, mainly in the cities.

A classical control point determination in the field is therefore, and for economic reasons to be excluded. It is on the other hand not necessary because of the reduced demands of accuracy.

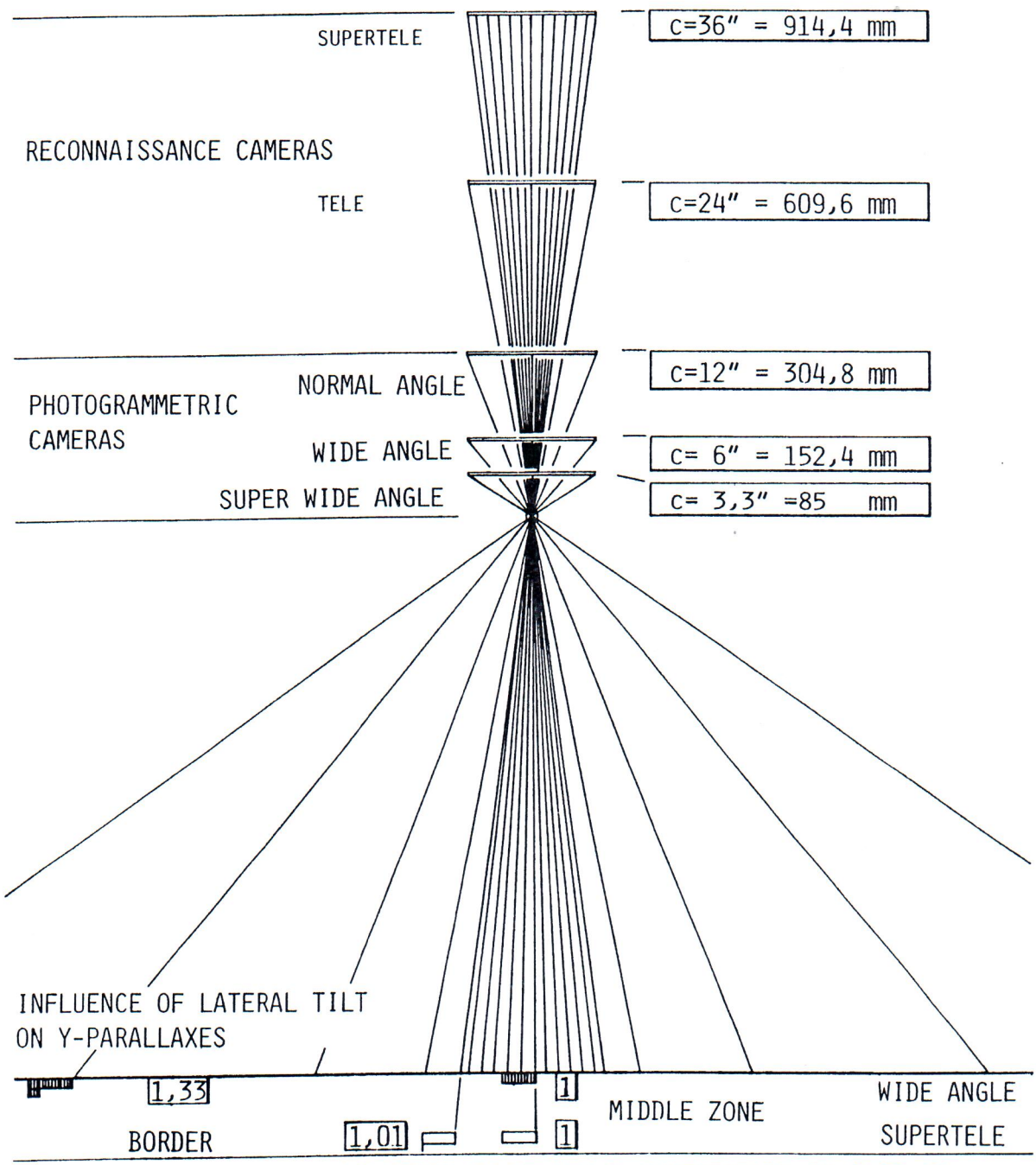
Digitizing the terrain coordinates in large scale maps (e.g. German Base Map

1 : 5 000) has proofed to be suitable and economic (ref. chapter 4).

The aim of the plotting procedure is to save the terrain coordinates of unexploded bombs on a data base. At any time these data can be recalled and replotted.

A countrywide data acquisition of all bombs would allow an immediate reaction in case of planned constructions in order to localize and to disarm all bombs in a well defined area.

FIG. 1 **FOCAL LENGTHS AND ANGLES OF RECONNAISSANCE AND PHOTOGRAMMETRIC CAMERAS**



PROBLEMS OF NUMERICAL SOLUTION OF RELATIVE ORIENTATION IN CASE OF SUPERTELE STEREOMODELS — SMALL BUNDLE OF RAYS —

MEASUREMENT OF UP TO 25 Y-PARALLAXES IN THE STEREOSCOPIC AREA HELPS TO OVERCOME THESE PROBLEMS

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3. CHOISE OF THE PLOTTER SYSTEM

As unexploded bombs are rarely found exactly under the spot which was photographed, but, depending on the direction of the bombing attack, apart from this spot /2/ it is not realistic to ask for a higher accuracy than 1 m.

Analytical precision plotters are therefore too expensive for the task. The orientation and measurement process is not the bottle-neck of the problem. Selection, determination and checking of control points is the real problem for which these plotters will not promise a considerably higher efficiency.

The decision was made for the STEREOCORD G3 system of ZEISS, Oberkochen (FRB), a computer-assisted measuring instrument which was originally designed for quantitative photointerpretation purposes /3/. It is highly flexible in accepting diversified image material (paper prints, diapositives, every focal length) and it is easily operated even by non-photogrammetrists.

The characteristic data are shown in FIG. 2 aiming its application for detection purposes.

4. METHOD OF LOCALIZATION OF UNEXPLODED BOMBS USING THE StereoData SYSTEM

The basic problem of connecting old stereo-photos with current maps for the purpose of precise X-Y-coordinate determination is explained in FIG. 3. After tests over several months the following method of orientation and plotting of reconnaissance photographs of World War II has proofed to be suitable:

- Interior Orientation using three fidicial marks in the stereoscopic part of each photo,
- Relative Orientation based on regularly 12 (maximum 25) Y-parallaxe measurements,
- Digitizing of planimetric control points from maps (Affine transformation using up to 9 map gridcrosses, automatic recording of the X-Y-coordinates of the digitized control point position),
- Absolute Orientation with plane similarity or affine transformation of the state plane coordinates by least squares adjustment and graphic representation of residual errors on the computer's screen,
- Online interconnection of Plotter and Stereomodel after Absolute Orientation for checking the quality of fitting. Digitizing further control points, erasing erroneous points if necessary,
- Skipping of control points for the zonewise plotting of stereo models,
- Single-Photo or double-photo affine transformations in case of divergent iterative orientation process,
- Checking the idendity of measured objects if several reconnaissance photo flights are available for one and the same area,
- Offline-reproduction of the data base contents in listings and maps,
- Updating of the data base (e.g. change of the object's characteristics "measured", "detected", "disarmed" ...).

The underlined characteristics were especially introduced in the StereoData system, they are extensions of the Standard Software package of STEREOCORD /4/.

In FIG. 4 the main features of the StereoData system are summed up.

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FIG. 2: Main features of the STEREOCORD G3 System

Stereocord G 3

ZEISS
West Germany

COMPUTERASSISTED **STEREOPLOTTING SYSTEM**

DEFINITION: STEREOCOMPARATOR WITH ELECTRONIC ACQUISITION OF COORDINATES X,Y OF THE LEFT PHOTO AND PARALLAXES PX, PY OF THE RIGHT PHOTO WITH RESPECT TO THE LEFT. RESOLUTION: 10 µ

APPLICATION FIELDS:

QUANTITATIVE **PHOTOINTERPRETATION** IN
- FORESTRY
- GEOLOGY
- PLANNING
- ENVIRONMENT PROTECTION

PHOTOGRAMMETRY
- TRAINING
- AEROTRIANGULATION
- MEASUREMENT OF DIGITAL TERRAIN MODELS
- DIGITAL MAPPING

TERRESTRIAL PHOTOGRAMMETRY
- ARCHITECTURAL PHOTOGRAMMETRY
- FACTUAL FINDINGS

ACCURACY:

PLANIMETRY ±20 TO ±30 µm IMAGE SCALE (σ_{xy})

HEIGHT ± 0.02 % * h_g (σ_z)

EXAMPLES:	PHOTO SCALE 1:5000			PHOTO SCALE 1:10000		
FOCAL LENGTH	hg	σ_{xy}	σ_z	hg	σ_{xy}	σ_z
c=304,8 mm =12"	1500 m	10-15 cm	0,3 m	3000 m	20-30 cm	0,6 m
c=609,6 mm =24"	3000 m	10-15 cm	0,6 m	6100 m	20-30 cm	1,2 m
c=914,4 mm =36"	4600 m	10-15 cm	0,9 m	9100 m	20-30 cm	1,8 m

THE RESULTS ARE VALID FOR PHOTOGRAMMETRIC IMAGE QUALITY ! IN CASE OF OLD RECONNAISSANCE PHOTOGRAPHS ERRORS ARE 2X OR 3X HIGHER !

SYSTEM G3 SUITABLE FOR **DETECTION** OF **UNEXPLODED BOMBS** (U.X.B.)

NO RESTRICTION OF **FOCAL LENGTHS**
STRICT ADJUSTMENTS FOR **ORIENTATION**
NO LIMITATION OF **TILTS**
ACCURACY OF THE INSTRUMENT BETTER THAN **IMAGE QUALITY**
INTERCONNECTION OF **MODEL** AND **MAP** / PLOTTING /**DATA BASE**

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FIG. 3: Principle of interconnecting photo pair and map in the StereoData System

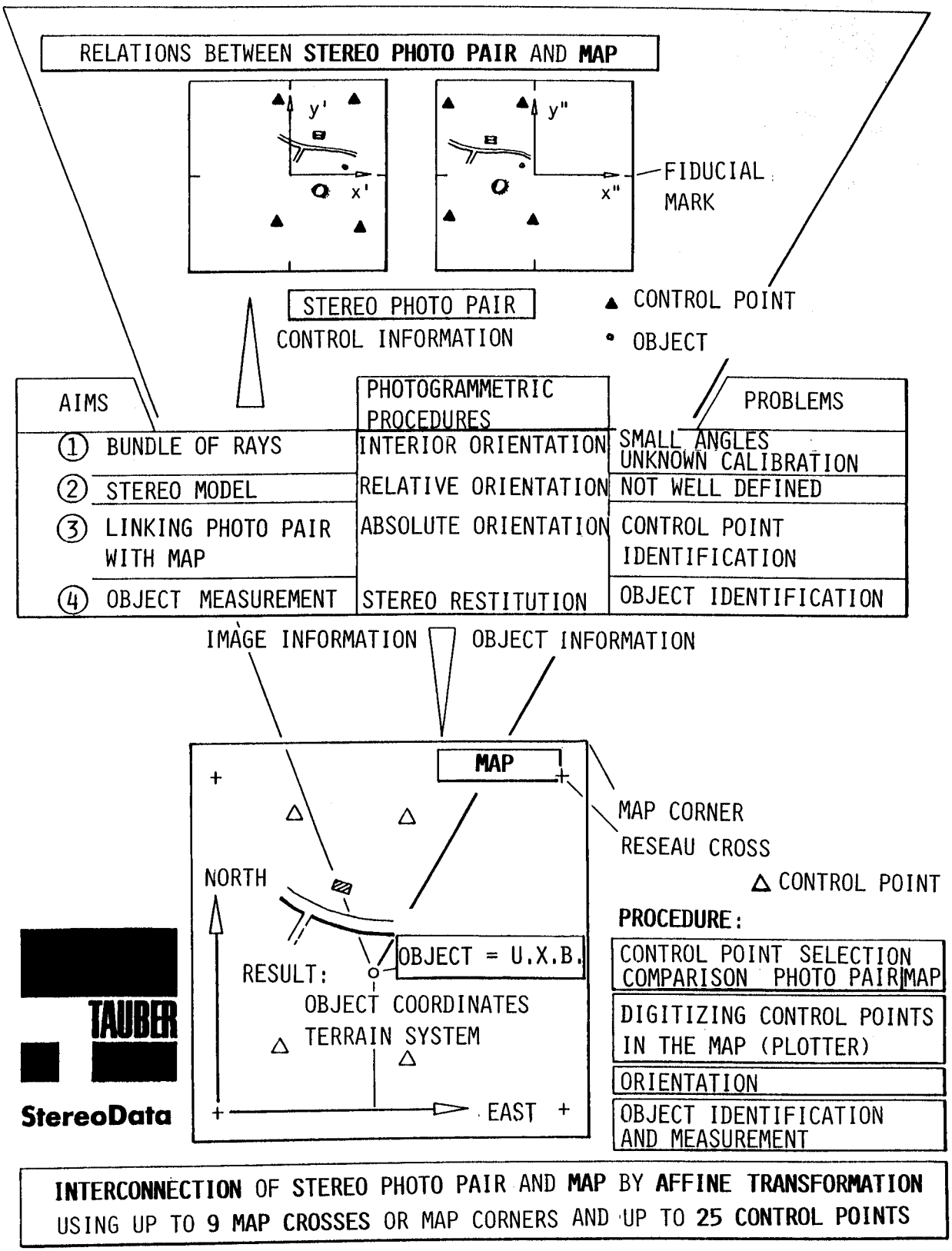

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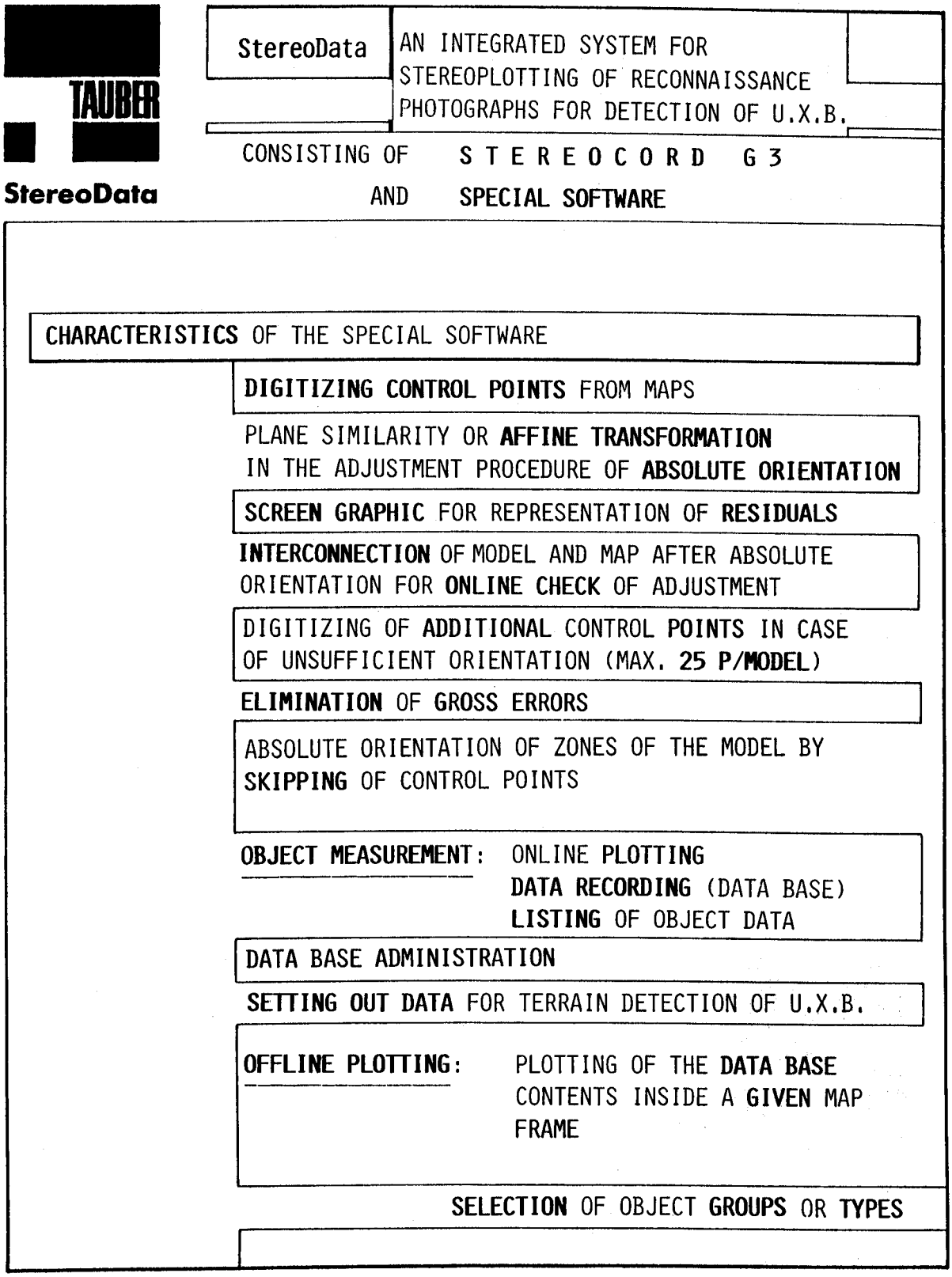
FIG. 4: Characteristics of StereoData system



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Schriftenreihe, Heft 12, 1987

REFERENCES

/1/ TAUBER, H.: Kompetenz und Ökonomie der Luftbildauswertung auf Kampfmittel, Lecture, Presentation of StereoData system, Münster, 1985

/2/ ULMER, H.J.: Historie der Luftbildauswertung auf Kampfmittel, Lecture, Presentation of StereoData system, Münster, 1985

/3/ MOHL, H./SCHWEBEL, R.: The ZEISS STEREOCORD for manifold measuring interpretation applications, IAP, Vol. 25 - A7, Rio de Janeiro, 1984

/4/ MOHL, H.: StereoData: Pflichtenheft und Programmierung für die Kampfmittelräumung, Lecture, Münster, 1985

ABSTRACT

This paper describes the problem of localization of unexploded bombs of World War II using old reconnaissance serial photographs.

The StereoData system is presented which consists of the analytical measuring instrument STEREOCORD G3 and of special software. It allows the economic determination of planimetric terrain coordinates of unexploded bomb hits with operational accuracy and high reliability.

The countrywide restitution and recording on a data base permits immediate localization and disarmement of objects in the field based on setting out data.

LOKALISIERUNG NICHT DETONIERTER SPRENGBOMBEN DES ZWEITEN WELTKRIEGS DURCH LUFTBILDVERGLEICH

ZUSAMMENFASSUNG

Die Problematik der Lokalisierung nicht detonierter Sprengbomben aus dem Zweiten Weltkrieg mit Hilfe alter Luftaufklärungs-Reihenaufnahmen wird erläutert.

Das StereoData-System wird vorgestellt, das aus dem analytischen Meßgerät STEREOCORD G3 und speziell entwickelter Software besteht. Es erlaubt die rationelle Bestimmung der Lagekoordinaten von Blindgänger-Einschlagstellen mit praxisgerechter Genauigkeit und hoher Zuverlässigkeit.

Die landesweite Auswertung und Registrierung in einer Datenbank läßt im Bedarfsfalle die rasche Ortung und Räumung von Blindgängern mit Hilfe von Absteckungsdaten zu.

Prof. Dr.-Ing. H. Mohl
IPO Stuttgart
c/o Fachhochschule für Technik
Willi-Bleicher-Straße 29
D-7000 Stuttgart 1

H. Tauber
Firma K.A. Tauber Spezialbau KG
Virnkamp 26
D-4400 Münster

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