RESEAU CAMERAS FOR ARCHITECTURAL PHOTOGRAMMETRY

Jürgen Peipe

Bundeswehr University Munich
Institute for Photogrammetry and Cartography
D-8014 Neubiberg, Germany

ABSTRACT

A large number of projects in architectural photogrammetry has been carried out by means of réseau cameras instead of conventional metric cameras. In this paper, first a brief report on the state-of-the-art of analogue sensor technology for the recording of buildings is given. Following the detailed discussion of réseau technique, two new réseau cameras are introduced, the 4 x 5" METRIKA 45 and the 60 x 120 mm TECHNORAMA 612 M. Technical specifications and, in particular, the film flattening and calibration strategy are outlined. First experiences in the application of these cameras to the photogrammetric survey of architectural objects are presented.

Keywords: Architectural Photogrammetry; Camera; Réseau Technique.

1. RESEAU TECHNIQUE

In recent years, the equipment used for recording architectural objects has changed substantially. This statement holds true as well for the design, size and technical details as for the availability of the imaging systems. Conventional metric cameras such as Wild P31 and P32, Zeiss TMK and SMK (see ATKINSON (1989) for a synopsis of metric cameras) are disappearing from the market for economic reasons. The UMK of Zeiss (Jena) is one of the last genuine metric cameras which is being manufactured up to now. Metric cameras have been effectively used in the recording of buildings and monuments world-wide, but they are too cumbersome and often unflexible for quite a series of photogrammetric tasks.

As a consequence, for many years off-the-shelf standard photographic cameras, that means non-metric cameras of 24 x 36 mm and 60 x 60 mm image format have been applied (GEORGOPOULOS 1990). They are small, light-weight, easy to handle and relatively inexpensive, and provide professional photo-technique such as interchangeable lenses, automatic exposure control, motorized film transport and a wide range of system accessories. Besides, a great variety of films with different emulsions is available.

In order to achieve an accuracy of the photogrammetric object restitution comparable to the metric camera approach such a non-metric camera has to be equipped with a réseau plate, that means a glass plate with cross-shaped marks in front of the film surface (WESTER-EBBINGHAUS 1983 and 1989a; see also Fig. 7). This type of camera is called partial metric or semi-metric and may be represented by some specially adapted Hasselblad, Leica and Rollei models (Table 1).

The réseau allows for the correction of systematic image errors caused by the

unflatness of the film surface during exposure and any deformation coming from the photo-processing. The grid crosses are recorded on the film by front-projection at the instant of exposure. The imaged cross positions can be measured and the displacements as against their precisely calibrated counterparts on the réseau plate are used to eliminate the film deformation effects by numerical transformation into the réseau plane. For this transformation, different methods are feasible. Apart from two-dimensional polynomials which apply to the entire image a meshwise interpolation approach is recommendable (KOTOWSKI 1984).

Besides, the réseau establishes an image coordinate system common to all photographs taken by one and the same camera. The position of the perspective centre in image space and the lens distortion can be calculated in relation to this frame of reference by camera calibration (see e.g. FRYER 1989, WESTER-EBBINGHAUS 1989b). Focusing stops ensure that these calibration data, if they are once determined, are reproducible, e.g. within ± 30 - 50 μm for the ROLLEIFLEX 6006 metric. This value applies to the principal distance and the coordinates of the principal point, a value of less than ± 5 μm belongs to the lens distortion (WESTER-EBBINGHAUS 1983; PEIPE 1986).

Such figures are satisfactory for most tasks in architectural photogrammetry. However, the camera can also be calibrated simultaneously with the object restitution process ("on-the-job") if necessary. For this, multi-station photo-triangulation by bundle adjustment is the essential tool to obtain the best fit of all parameters of interior and exterior orientation together with the computation of three-dimensional object coordinates (e.g. KOTOWSKI et al. 1983 and 1988).

An unavoidable drawback of the réseau technique is given by the fact that the réseau has to be measured in addition to the imaged object information. But, in order to meet the accuracy requirements in architectural photogrammetry, normally, it is not necessary to work with the full set of réseau marks, e.g. the 11 x 11 crosses of the ROLLEIFLEX 6006 metric. Nevertheless, one has to determine how many marks must be measured in order to achieve a sufficient numerical film flattening.

Analytical photogrammetric methods of object restitution are fundamental to the efficient application of réseau technique because the camera characteristics are to be modelled mathematically. The image coordinates can be measured not only on a comparator or analytical plotter but on a digitizing tablet as a

Table 1 Réseau Cameras

Manufacturer	Type	Format [mm^2]	Lens [mm]
Leica	R5	24 x 36	15 - 180
Rollei	3003	24 x 36	15 - 135
Rollei	35	24 x 36	40
Pentax	PAMS 645P	60 x 45	45
Hasselblad	IDAC	60 x 60	38,70
Rollei	6006	60 x 60	40 - 350
GSI Inc.	CRC -2 *	115 x 115	65, 90, 120
GSI Inc.	CRC -1 *	230 x 230	120, 240
Rollei	LFC	230 x 230	165, 210
Linhof	TECHNORAMA 612 M	60 x 120	65, 135
Linhof	METRIKA 45	95 x 120	75, 90, 150

* with rear-projected réseau marks

simple and inexpensive device (measurement of enlarged paper prints with ROLLEIMETRIC MR2, ELCOVISION 10 etc.).

The combination of small format réseau camera, digitizer, personal computer and analytical data-reduction software represents an equipment suitable for economical architectural photogrammetry. In addition, photographs taken with film-based cameras can be digitized by a scanner and then measured on a personal computer or on a workstation by means of digital image processing (PHIDIAS (BENNING and EFFKEMANN 1990), DVP (GAGNON et al. 1990) etc.).

2. RESEAU CAMERAS

During the last 10 years, a lot of work in architectural photogrammetry has been successfully performed by means of réseau cameras. Consequently, the réseau technique is well-established nowadays. Réseau cameras available on the market are listed in Table 1.

Keeping in mind that the GSI cameras and the Rollei LFC are specifically designed for industrial photogrammetric applications it becomes obvious that the largest practical format for architectural survey has been 60 x 60 mm. Therefore, two cameras providing a larger usable film format have been newly developed in cooperation of the Institute for Photogrammetry and Cartography of the Bundeswehr University Munich, the BMW company and, of course, the camera manufacturer, the Linhof company in Munich. The METRIKA 45 (PEIPE 1990) and the TECHNORAMA 612 M may fill the gap between partial metric cameras of 60 x 60 mm image format and the metric UMK of 130 x 180 mm (Table 1).

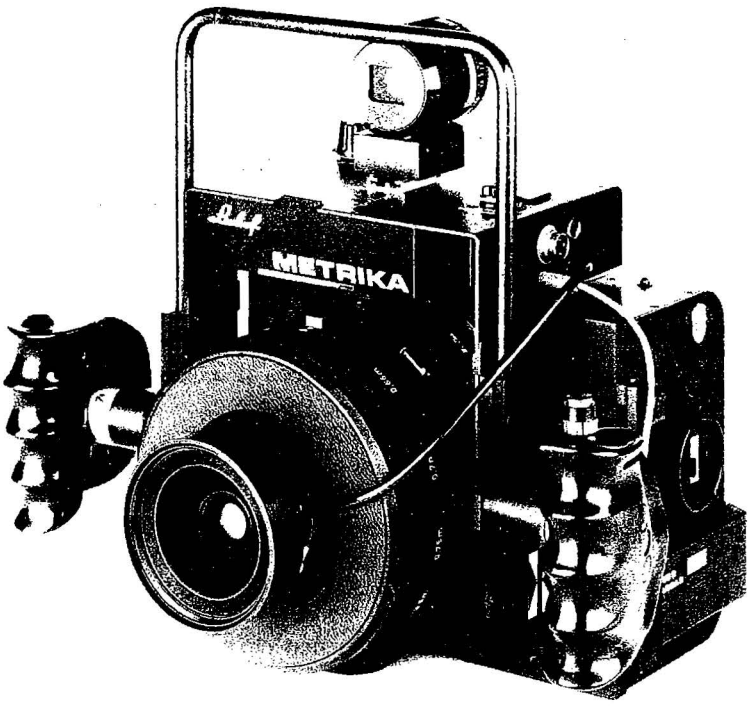


Figure 1 Front view of the METRIKA 45 (90 mm lens)

3. METRIKA 45

The aim was to develop a robust and universally applicable camera which in spite of the 4 x 5" format remains rather handy and fully portable to be used on location and even for hand-held shots.

Figure 1 presents an overall view of the METRIKA 45 and Table 2 gives the technical specifications. The camera housing consists of a black anodized aluminium body with permanently mounted lens in a heavy-duty barrel. Three lens systems, 75 mm and 90 mm wide angle and 150 mm normal lens, are available. Each lens cone is equipped with focusing stops which reproducibly determine a set of interior orientation parameters. A réseau plate is built into the camera body forming a rigid unit with the integrated lens barrel. The réseau plate is interchangeable to enable the use of different grid configurations.

A vacuum rollfilm back (Fig. 2) is attached to the camera-plus-lens housing. Standard 126 mm black-and-white or color rollfilm is suitable. For easy film change in daylight, the film magazine is provided with a hinged cover and a swing-out film carrier that do not have to be removed. Daylight loading cartridges accept approximately 5 m of film, that is equivalent to about 50 exposures.

All the camera operations such as vacuum pump, shutter release and film transport are fully motorized and electronically controlled. Multiple exposures, flash synchronization and simultaneous release of several cameras are possible. A data imprint module is installed in the rollfilm magazine. Exposure metering is only accomplished by external exposure meters.

Table 2 METRIKA 45 specifications

Format	4 x 5" (effective negative area 93 x 116 mm)
Film	126 mm rollfilm (e.g. Agfa Aviphot Pan, Kodak Technical Pan, Agfacolor or Agfachrome Aero)
Lens	1) Schneider Super Angulon 5.6/75 mm (wide angle lens) diaphragm scale f/5.6 to f/45, shutter speed range $^1/_{250}$ to 32 sec and B focusing mount with 16 click stops from 0.65 m to ∞ 2) Schneider Super Angulon 5.6/90 mm (wide angle lens) focusing mount with 16 click stops from 0.65 m to ∞ 3) Schneider Apo-Symmar 5.6/150 mm (normal lens) focusing mount with 13 click stops from 1.2 m to ∞
Réseau options	1) 10 mm grid spacing (9 x 11 crosses cover an 80 x 100 mm frame) 2) some crosses at the border of an 80 x 100 mm frame 3) 2.5 mm grid spacing (crosses cover the entire negative area)
Power supply	rechargeable NC battery integrated into the camera control unit or external power supply
Weight	about 10 kg
Dimensions	about 300 x 365 x 340 mm

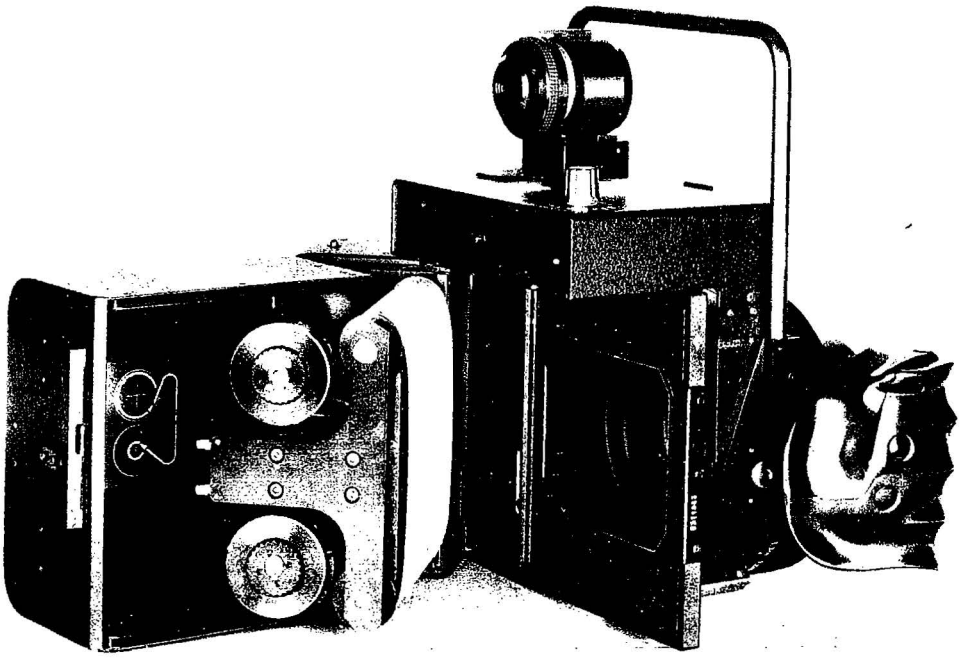


Figure 2 METRIKA 45: on the left the open rollfilm magazine with film cassettes and vacuum plate, on the right the camera housing with lens, réseau plate, control unit, optical viewfinder and handgrip

The METRIKA offers two possibilities of film flattening: a vacuum system and réseau technique. Réseau plates of different grid spacing are available on a custom order basis (Table 2). In general, the dimensionally stable rollfilm is properly flattened against the vacuum plate of the film magazine. Therefore, a limited number of réseau marks at the border of an 8 x 10 cm frame of the camera are enough to determine and eliminate the global film deformation, that means linear dimensional changes of the film. If a higher quality of numerical film flattening is required or the correct flattening is to be proved, respectively, a réseau of higher density (9 x 11 crosses) should be chosen. At last, the réseau with 2.5 mm grid spacing is recommendable to high-accuracy industrial applications only.

Each click stop of the focusing mount defines a special set of interior orientation parameters that has to be determined by a camera calibration procedure. Due to the stability of the METRIKA these calibration data remain unchanged, that means they don't differ significantly after some months of work. In this regard, the METRIKA can be considered a metric camera. The photographs are suitable for measurement on analytical plotters, mono- or stereo-comparators, and so-called simple (analytical) systems.

In the following, first applications of the new camera in the recording of buildings and monuments are briefly mentioned. The photogrammetric survey of the cathedral of Siena in Italy (KOTOWSKI et al. 1989, FELLBAUM and WOYTOWICZ 1989) has been partially carried out by the METRIKA. Figures 3 and 4 show photographs intended for bundle triangulation and the detailed restitution of the facades. The second example is concerned with the recording of the city hall of Schwäbisch Gmünd performed in cooperation with the Landesdenkmalamt Baden-Württemberg in Germany (Fig. 5)

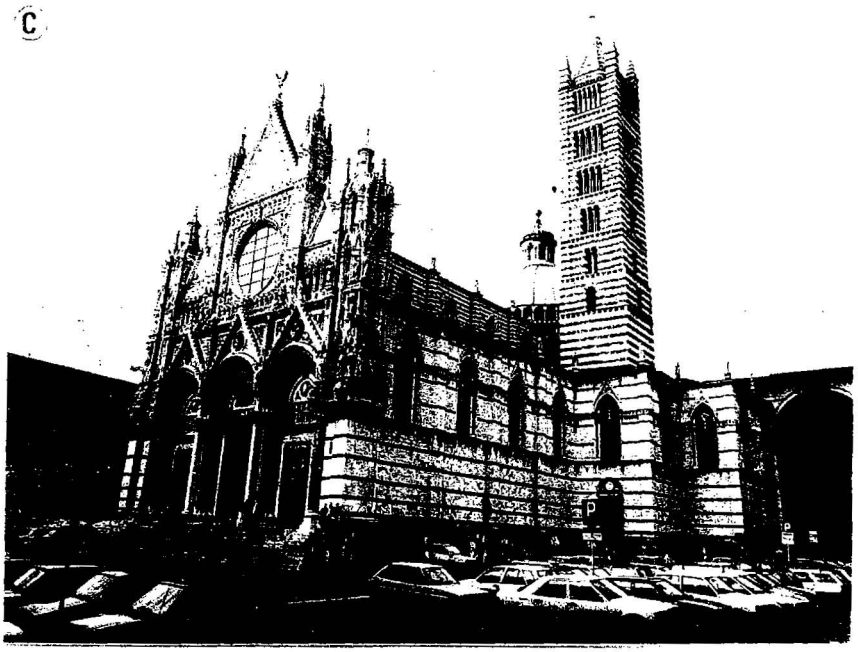
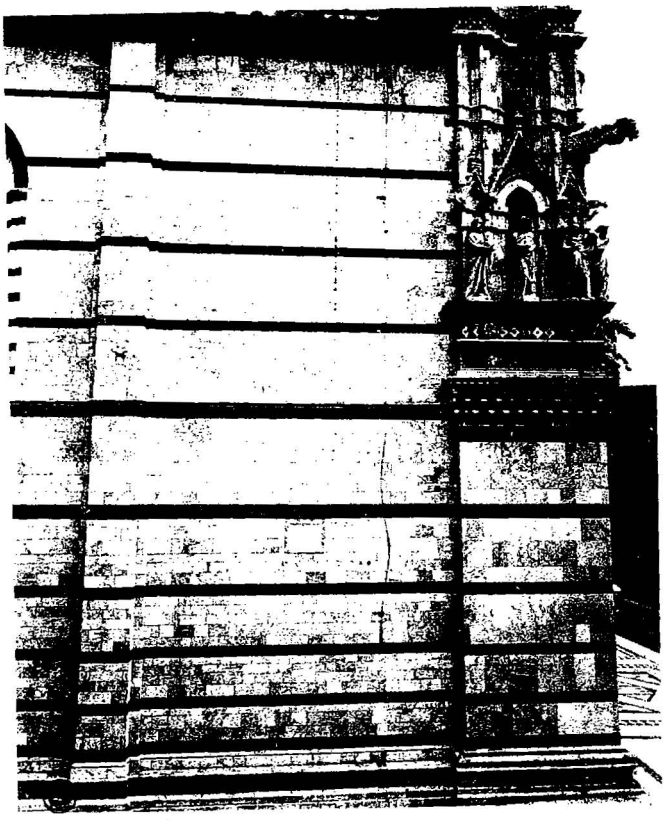


Figure 3



Cathedral
of Siena

Figure 4

4. TECHNORAMA 612 M

The second newly developed photogrammetric camera is based on the Linhof TECHNORAMA 612 PC, a sophisticated imaging system with the uncommon panoramic photo format of 60 x 120 mm (Fig. 6). The panoramic effect does not originate from a panoramic or super wide angle or fisheye lens. But from a standard high quality wide angle or normal lens which is masked to obtain an effective negative area of 55 x 110 mm.

Some technical specifications of the TECHNORAMA 612 M are displayed in Table 3. Any 120 and 220 rollfilm just as appropriate for 60 x 60 mm cameras can be used. Interchangeable lenses of 65 mm (wide angle) and 135 mm (normal lens) are available. The TECHNORAMA is designed as a manually operated camera, without vacuum system, automatic controls or motorized operation, featuring maximum machanical and optical precision.

The conversion from a non-metric into a semi-metric camera is done by mounting a réseau plate (Fig. 7) and installation of click-stop focus settings. For a first investigation, a small grid spacing of 2.5 mm was chosen. Preliminary test results indicate that 5 mm will be sufficient for a precise object reconstruction. Experience regarding the stability of the interior orientation parameters for a long period of time does not exist yet.

The panoramic image format promotes the photogrammetric survey of tall buildings such as church towers and other high-rise objects. On the other hand, stereophotography can be advantageously performed by means of the TECHNORAMA due to the large overlapping model area compared to square 60 x 60 mm photo format. Once again, the first test object for the new camera was the cathedral of Siena (Figs. 8 and 9).

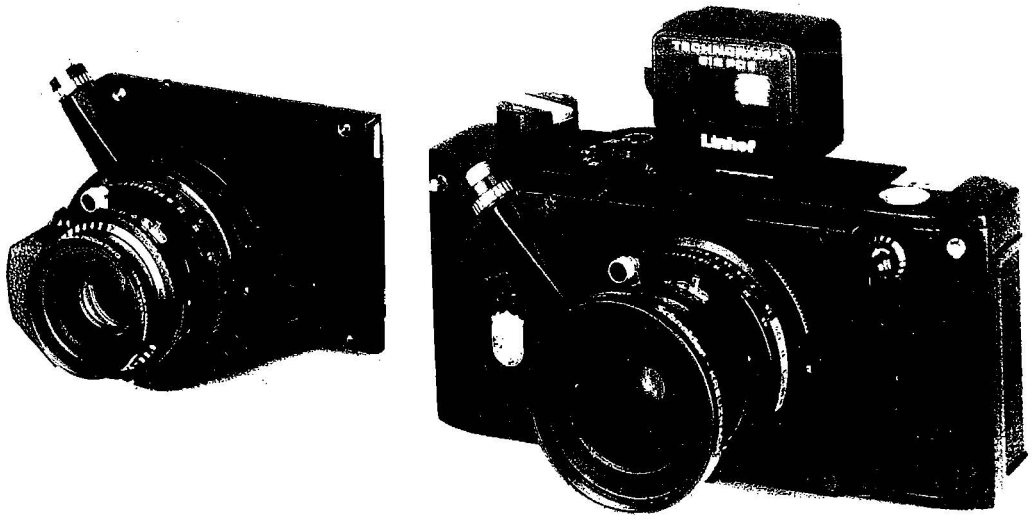


Figure 6 TECHNORAMA 612 M with 65 mm lens and, on the left side, the 135 mm lens

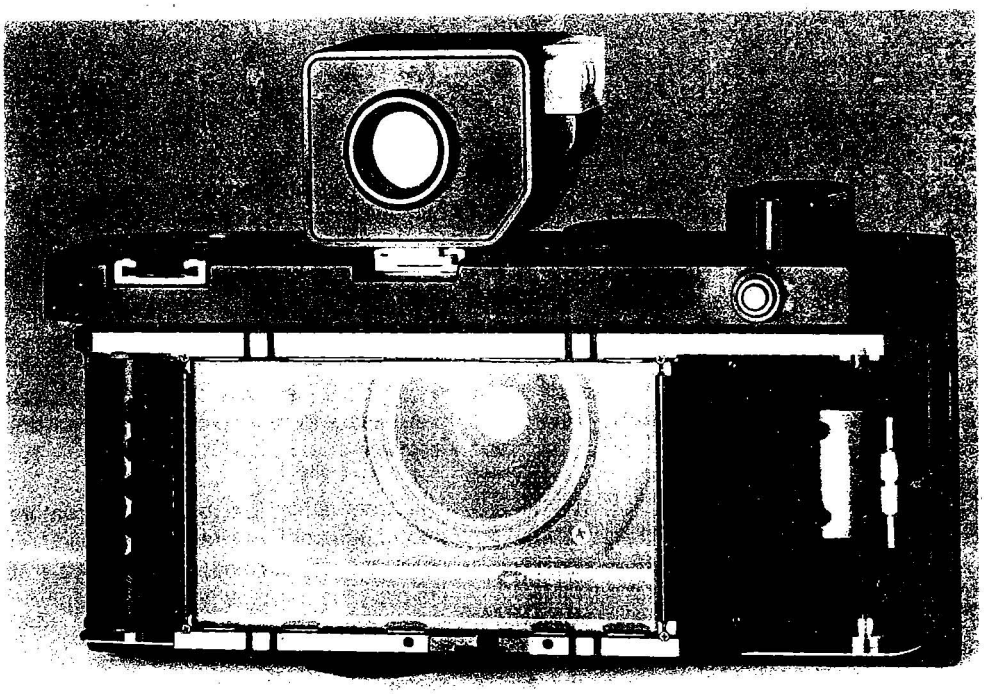
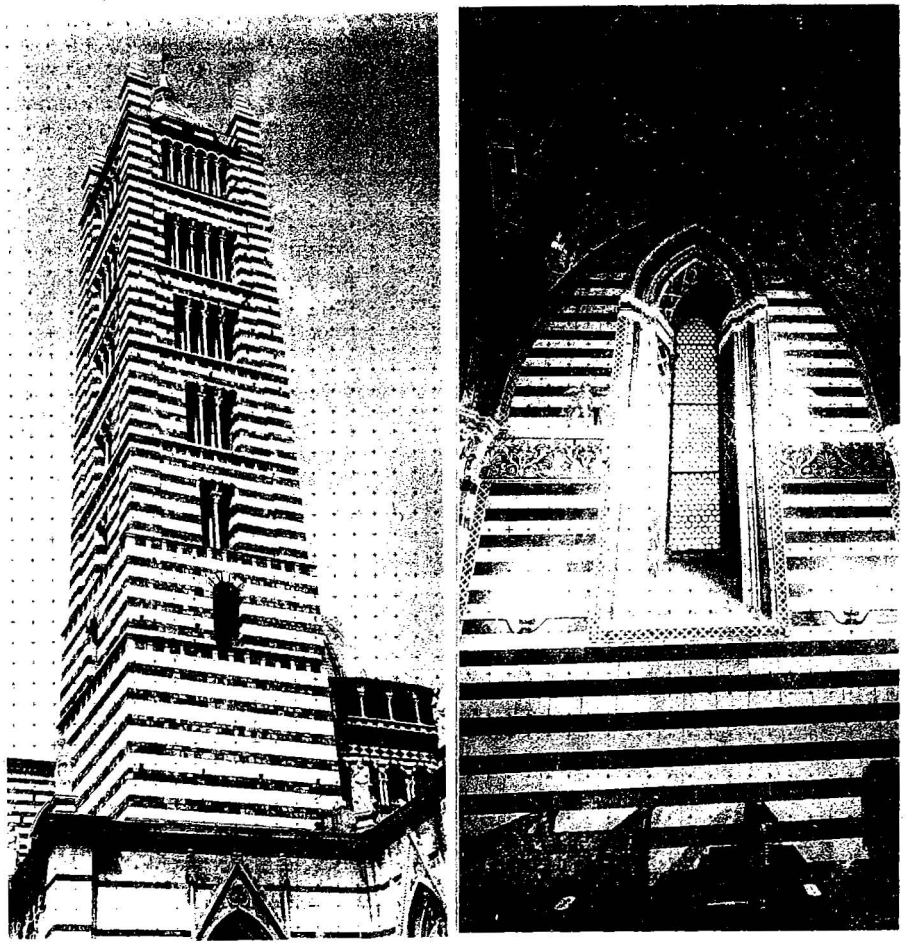


Figure 7 TECHNORAMA 612 M with réseau plate (view from the rear; camera back is removed)

Table 3. TECHNORAMA 612 M specifications

Format	60 x 120 mm (effective negative area 55 x 110 mm)
Film	rollfilm 120 or 220 for 6 or 12 photographs resp.
Lens	1) Schneider Super Angulon 5.6/65 mm (wide angle lens) diaphragm scale f/5.6 to f/45 shutter speed range 1/500 to 1 sec, B and T focusing mount with 12 click stops from 0.9 m to infinity 2) Schneider Apo-Symmar 5.6/135 mm (normal lens) focusing mount with 10 click stops from 3.5 m to infinity
Weight	about 2 kg
Dimensions	about 220 x 150 x 130 mm (with 65 mm lens)



Figures 8 and 9 Siena: tower and baptistry of the cathedral

5. CONCLUDING REMARKS

Réseau cameras are well introduced and proven image acquisition systems in architectural photogrammetry. In combination with analytical data reduction procedures, the réseau technique can be successfully applied. The new cameras presented in this paper overcome the photo format limitations of 24 x 36 mm and 60 x 60 mm cameras.

The development of methods for the photogrammetric recording of buildings and monuments is going on. Next step is the digital approach: digitized analogue photographs or digital images produced with CCD cameras are handled on powerful personal computers and workstations which provide image processing software.

In the near future, there will be a coexistence of several imaging systems, that means metric, semi-metric, non-metric and digital cameras, and also of several data reduction instruments and procedures. All these systems, if they are operational and effective, legitimize themselves. It is an important and serious function of the photogrammetrist to select the tools which fit best to a specific task or to support such a decision.

REFERENCES

ATKINSON, K. B., 1989: Instrumentation for Non-Topographic Photogrammetry. In: Non-Topographic Photogrammetry (Ed. H.M. Karara), American Soc. Photogr. & Remote Sensing, Falls Church / Virginia / USA, pp. 15-35

BENNING, W., EFFKEMANN, C., 1990: Adjustment and Image Processing of Scanned Photographs within a Graphical 3D-Editor. Int. Arch. Photogr. & Remote Sensing, Vol. 28/5.1 , SPIE Vol. 1395, Bellingham/Washington/USA, pp. 308-313

FELLBAUM, M., WOYTOWICZ, D., 1989: Photogrammetric Surveying and Representation of the Siena Cathedral. Presented Paper, XII. Int. Symp. Architectural Photogrammetry (CIPA), Oct. 1989, Rom, 8 p.

FRYER, J.G., 1989: Camera Calibration in Non-Topographic Photogrammetry, In: Non-Topographic Photogrammetry (Ed. H.M. Karara), American Soc. Photogr. & Rem. Sensing, Falls Church / Virginia / USA, pp. 59-69

GAGNON, P.-A., AGNARD, J.-P., NOLETTE, C., BOULIANNE, M., 1990: A Microcomputer-Based General Photogrammetric System. Phot. Eng. & Remote Sensing 56 (5), pp. 623-625

GEORGOPOULOS, A., 1990: Photogrammetric Potential of Small Format Photography. Int. Arch. Photogr. & Rem. Sensing, Vol. 28/5.1 , SPIE Vol. 1395, Bellingham / Washington / USA, pp. 128-137

KOTOWSKI, R., RÖSSMANN, H., WESTER-EBBINGHAUS, W., 1983: Zweischalige Bündeltriangulation an einem Großbauwerk. Zeitschrift für Vermessungswesen 108 (3), pp. 119-127

KOTOWSKI, R., 1984: Zur Réseaukorrektur von systematischen Bildfehlern. Bildmessung und Luftbildwesen 52 (2), pp. 96-101

KOTOWSKI, R., PEIPE, J., WESTER-EBBINGHAUS, W., 1988: Bundle Triangulation in Architectural Photogrammetry - The Basilica of San Francesco in Siena. Photogr. Record 12 (72), pp. 857-871

KOTOWSKI, R., MEID, A., PEIPE, J., WESTER-EBBINGHAUS, W., 1989: Photogrammetrische Bauaufnahme der "Kirchen von Siena" - Entwicklung eines Konzepts zur Vermessung von Großbauwerken. Allgemeine Vermessungs-Nachrichten (AVN) 96 (4), pp. 144-154

PEIPE, J., 1986: Interior Orientation Stability of a Partial Metric Camera - An Experimental Study. Int. Arch. Photogr. & Rem. Sensing, Vol. 26/1, ESA SP-252, ESTEC Noordwijk / The Netherlands, pp. 171-178

PEIPE, J., 1990: Eine neue 4" x 5" Aufnahmekammer für die Nahbereichsphotogrammetrie. Int. Arch. Photogr. & Rem. Sensing, Vol. 28/5.1 , SPIE Vol. 1395, Bellingham / Washington / USA, pp. 256-263

WESTER-EBBINGHAUS, W., 1983: Ein photogrammetrisches System für Sonderanwendungen. Bildmessung und Luftbildwesen 51 (3), pp. 118-128

WESTER-EBBINGHAUS, W., 1989a: Das Réseau im photogrammetrischen Bildraum. Zeitschrift für Photogrammetrie und Fernerkundung (BuL) 57 (3), pp. 64-71

WESTER-EBBINGHAUS, W., 1989b: Trends in Non-Topographic Photogrammetry Systems. In: Non-Topographic Photogrammetry (Ed. H.M. Karara), American Soc. Photogr. & Rem. Sensing, Falls Church/Virginia/USA, pp. 377-387