XIII Congress of the
International Society for Photogrammetry
Helsinki, 1976

Report of Commission V

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Non-Topographic Photogrammetry, 1972-1976

Introduction

This report highlights the activities of ISP Commission V during the past four years and sketches the major trends in the development of non-topographic photogrammetry throughout the world during that period. The improvements to terrestrial and close-range photogrammetric equipment, introduced since 1972, are summarized. The increase in the use of non-metric cameras in non-topographic photogrammetry is discussed.

Highlights of the Activities of Commission V

The activities of Commission V between 1972 and 1976 were based mostly on the resolutions adopted at the end of the Twelfth ISP Congress in Ottawa in 1972, together with the suggestions subsequently received from the President and Council of ISP.

Resolutions of Commission V at the Ottawa Congress

The resolutions of Commission V at the XII ISP Ottawa Congress in 1972 read:

"Commission V recommends:

1. To continue and further develop the following areas of study:
   - 1.1. Calibration of terrestrial, close-range and micro-range photogrammetric systems;
   - 1.2. Analytical and semi-analytical approaches in the systems mentioned in 1.1 above; and
   - 1.3. Metrical aspects of non-conventional imageries, with emphasis on thermal imageries and holography.
2. To undertake the following additional studies:
   - 2.1. Photogrammetric potentials of non-metric cameras in photogrammetric systems, and
   - 2.2. Basic concepts of application of photogrammetry in quality control in industry.
3. Develop cooperative efforts between ISP and appropriate international organizations in the biomedical and bioengineering fields."

Activities Related to Resolutions 1.1 & 1.2

Working Group V/1, chaired by Professor Dr. K. Linkwitz, Stuttgart University, was established in November 1972 to study the theme "Analytical and Semi-Analytical Approaches in Terrestrial, Close-Range, and Micro-Range Photogrammetry". The following themes of interest evolved:

- Calibration of terrestrial, close-range, and micro-range photogrammetric systems;
- Close-range and micro-range photogrammetric systems;
- Accuracy of close-range and micro-range restitutions
- General concepts of analytical and semi-analytical approaches, with emphasis on numerical computer-adaptable solutions; and
- Analytical and semi-analytical approaches to quality control in industry.

During the Helsinki Congress, this most active Working Group will have a strong program encompassing two technical sessions. In the session "Analytical Methods in Close-Range Photogrammetry," three invited papers are planned on "Mathematical Formulations and Digital Analysis in Close-Range Photogrammetry", *K.W. Wong (USA);* "Analytical On-Line Systems In Close-Range Photogrammetry", *V. Kratky (Canada);* "Analytical Solutions in Terrestrial Photogrammetry", *J.P. Kienko (USSR).*

In the session "Accuracy Aspects and Instrumentation in Close-Range Photogrammetry" three invited papers are planned: Accuracy of Close-Range Photogrammetry, *P.*

Hottier (France); Calibration of Close-Range Photogrammetric Systems: Mathematical Formulation, *W. Faig (Canada);* and Implementation and Practical Experience, *M. Döhler (FRG).*

Another major event related to Resolutions 1.1 and 1.2 is the ASP Symposium on Close-Range Photogrammetric Systems which was held on the Urbana-Champaign Campus of the University of Illinois in July 1975. This meeting was sponsored by the American Society of Photogrammetry in cooperation with ISP Commission V and the University of Illinois. Pertinent information about this symposium is given later in this report.

Analytical methods are now used extensively in non-topographic photogrammetry. Substantial progress in this area has taken place during the past four years and great strides are expected in the immediate and near future.

ACTIVITIES IN RESPONSE TO RESOLUTION 1.3

Working Group V/3 was established in November 1972 to study the theme "Metrical Aspects of Non-Conventional Imageries, with Emphasis on Holography and Thermal Imageries." This Working Group was headed by Professor Dr. E.M. Mikhail, Purdue University, until September 11, 1974; thereafter, Dr. M.K. Kurtz, Jr., U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia, headed the group.

In Helsinki, Working Group V/3 will be in charge of one session (Holographic and Moiré Systems and Applications in Close-Range Photogrammetry). The following invited papers are planned for this session: "Three-Dimensional Location and Measurement by Coherent Optical Methods," *J.W.C. Gates (UK);* "Simultaneous All-Around Measurement of a Living Body by Moiré Topography," *H. Takasaki (Japan);* "Comparison of Optical Contouring Methods," *N. Balasubramanian (USA);* and "Canadian Contribution to Hologrammetry," *J.P. Agnard (Canada).*

Members of this energetic working group actively participated in the Symposium on Coherent Optics in Mapping organized by the Society of Photo-Optical Instrumentation Engineers (SPIE) in March 1974, the March 1975 Convention of the American Society of Photogrammetry, and the July 1975 ASP Symposium on Close-Range Photogrammetric Systems. Dr. Kurtz compiled an extensive bibliography on "Potential Application of Holography in Photogrammetry and Mapping." While no direct application of the hologrammetric measurement techniques has been reported in the open literature so far, it is universally believed that coherent optics have the potential to play a number of key roles in a wide variety of non-topographic photogrammetric systems of the future.

ACTIVITIES RELATED TO RESOLUTION 2.1

Working Group V/2, chaired by Professor Dr. W. Faig, University of New Brunswick, was formed in November 1972 to study the "Photogrammetric Potentials of Non-Metric Cameras." The following major points of interest were identified within the overall theme of this Working Group:

- Definition and classification of non-metric cameras.
- Calibration of non-metric cameras:
  Methods and parameters; comparison of approaches,
  Accuracy and tolerances,
  Repeatability and recalibration,
- Ojbect-space control requirements and actual determination of control,
- Comparison of metric and non-metric photogrammetry in terms of feasibility, economy, and simplicity,
- Evaluation of non-metric photography and instrumentation used,
- Practical and experimental experiences, especially in the area of quality control in industry.

At the Helsinki Congress, two sessions will be devoted to the activities of this most active Working Group. In the session entitled "Problems Associated with the Use of Non-Metric Cameras in Photogrammetry," Dr. Faig plans to report on an extensive survey he conducted on the use of non-metric cameras throughout the world. This session will also feature the invited paper "Accuracy Aspects Concerning the Interior Orientation of Non-Metric Cameras," *O. Kölbl (Switzerland).*

In the session devoted to "Practical Experience with Non-Metric Photography", one invited paper is planned: "The Use of Non-Metric Cameras in Monitoring High-Speed Processes, *M.C. van Wijk and H. Ziemann (Canada).*

This session also will feature a panel discussion on "The Actual Use of Non-Metric Cameras in Photogrammetric Practice." Invited panelists will include the following colleagues: J. Badekas (Greece), I.A. Harley (Australia), J. Höhle (USA), O. Jacobi (Denmark), G. Ladouceur (Canada), H. Schöler (GDR), Z. Sitek (Poland); W. Faig (Canada), moderator.

The photogrammetric potential of non-metric cameras was one of the main topics of discussion at the July 1975 ASP Symposium on Close-Range Photogrammetric Systems. From all indications, it seems that non-metric cameras are starting to gain general accept-

ance as vehicles for data acquisition in an increasing number of areas of application of close-range and micro-range photogrammetry. It is felt that opening the door for the use of readily available and relatively inexpensive non-metric cameras in photogrammetric systems, along with metric cameras, would enable numerous engineers and scientists in several disciplines to make full use of the technical and economical advantages of photogrammetry. Freeing the photogrammetric systems from the restrictions of conventional hardware, through the use of analytical procedures and non-metric cameras, is one of the major goals of current research work in close-range and micro-range photogrammetric systems.

ACTIVITIES RELATED TO RESOLUTION 2.2

Whereas no working group or committee was formally organized to deal with the implementation of this resolution, the topic "industrial photogrammetry" was advanced by the Commission on various fronts. Two sessions on non-topographic photogrammetry (with emphasis on industrial photogrammetry) were included in the Symposium of the UK Photogrammetric Society in Birmingham. At the ASP Symposium on Close-Range Photogrammetric Systems a session (six papers) was devoted to Engineering and Industrial Applications.

At the Helsinki Congress, a session will be devoted to Industrial Photogrammetry, with the following three invited papers planned: "A Review of Close-Range Engineering Photogrammetry," *K.B. Atkinson (UK);* "Close-Range Photogrammetry as an Aid to Measurement of Marine Structures," *I. Newton (UK);* and "Industrial Photogrammetry in Japan," *T. Oshima (Japan).*

ACTIVITIES IN RESPONSE TO RESOLUTION 3

An International Exploratory Committee on Biomedical Photogrammetry was formed in April 1974 to look into ways and means to begin to forge links between the photogrammetric and the medical communities to their mutual benefit and to advise the President of Commission V on what actions need to be taken in this direction. Members of the Committee are Professor Dr. R.E. Herron, Baylor College of Medicine, Chairman; Professor Dr. K. Torlegard, Royal Institute of Technology, Stockholm; and Mr. K.B. Atkinson, University College London. This Committee is expected to make preliminary recommendations during the Helsinki Congress.

Along the lines of international cooperation in the field of biomedical photogrammetry, the 1974 symposium of ISP Commission V (Bio-stereometrics '74) was a major first step.

At the 1975 ASP Symposium on Close-Range Photogrammetric Systems, a session (11 papers) was devoted to Biostereometrics.

At the Helsinki Congress, Biostereometrics will be the topic of one of the sessions. The program of this session is "Biostereometrics—A Progress Report," *R.E. Herron (USA);* Panel discussion of invited paper "Biostereometrics - A Progress Report", *F.G. Lippert (USA); K. Tolegård (Sweden); P.H. Burke (UK); H. Greuel (FRG); R. E. Herron (USA),* moderator.

SYMPOSIA AND SEMINARS

Several symposia and seminars dealing with one aspect or another of non-topographic photogrammetry were held during the past four years. The major events in which Commission V was involved, or on which details were given in the reports of the National Correspondents of the Commission, are discussed in the following paragraphs.

BIOSTEREOMETRICS '74

Commission V held an International Symposium on Biomedical and Bioengineering Applications of Photogrammetry, September 10-13, 1974 at the Washington Hilton Hotel in Washington, D.C. This meeting (Biostereometrics '74) was hosted by the American Society of Photogrammetry in conjunction with the XIV Congress of the International Federation of Surveyors (FIG). Fifty papers on a wide range of subjects within the field of Biostereometrics were presented. Preprinted proceedings were distributed to the registrants. Copies of these proceedings are available ($12.50) from the American Society of Photogrammetry.

THE UK PHOTOGRAMMETRIC SOCIETY'S SYMPOSIUM, BIRMINGHAM, 1975

Two sessions on Non-Topographic Photogrammetry were included in the week-end Symposium of The Photogrammetric Society (UK) in April 1975. ISP Commission V was represented in this meeting by its President and the Chairman of Working Group V/1. A comprehensive report on these two sessions of this highly successful symposium will be given by Mr. K.B. Atkinson during the first technical session of the Commission at the Helsinki Congress.

ASP SYMPOSIUM ON CLOSE-RANGE PHOTOGRAMMETRIC SYSTEMS, CHAMPAIGN, ILLINOIS, 1975

This meeting was sponsored by the American Society of Photogrammetry (Close-Range Photogrammetry Committee and Computa-

tional Photogrammetry Committee) in cooperation with ISP Commission V and the University of Illinois at Urbana-Champaign. The symposium was held July 28 - August 1, 1975 at the Ramada Inn Convention Center in Champaign, Illinois. Forty-nine papers dealing with the systems, software, and various applications of close-range photogrammetry were presented. Preprinted proceedings were distributed at the beginning of the meeting, and are available ($12.50) from the American Society of Photogrammetry.

ROUND-TABLE DISCUSSION AT IMEKO VI, DRESDEN, GDR, 1973

In the framework of the Sixth International Measurement Confederation (IMEKO VI) held in Dresden, GDR, June 17-23, 1973, a round-table discussion on the theme "Problems of Automatic Data Acquisition and Processing for Multi-Dimensional Measurement" was held. The president of ISP Commission V was invited to participate but, unfortunately, could not attend because of a prior commitment in Mexico City. A comprehensive report on this segment of IMEKO VI will be given by Prof. Dr. G. Lotze during the first technical session of Commission V at the Helsinki Congress.

SEMINAR ON NON-TOPOGRAPHIC APPLICATIONS, KIEV, USSR, 1974

This conference was held in October 1974 by the Ukranian Republic's House of Science and Technology in cooperation with the Institute of Civil Engineering in Kiev and Commission 5 of the National Committee of Photogrammetrists of the USSR.

INTERNATIONAL SYMPOSIA ON ARCHITECTURAL PHOTOGRAMMETRY

These symposia are highly successful annual events organized by the International Committee on Architectural Photogrammetry. During the reporting period, the sites of the symposia were Zürich (1972), Lucca (1973), Athens (1974), and London (1975).

INTERNATIONAL COMMITTEE ON ARCHITECTURAL PHOTOGRAMMETRY (CIPA)

Close contact and friendly cooperation have been maintained throughout the past four years with this most active Committee, which has been, since its inception in 1970, under the able chairmanship of Mr. M. Carbonnell. A report by Mr. Carbonnell on the activities of CIPA will be included in the first session of Commission V in Helsinki. Mr. Carbonnell has organized and will chair a session on Architectural Photogrammetry at the Helsinki Congress. Three invited papers are planned for this session:
Technical Progress in Architectural Photogrammetry," *M. Carbonnell (France);* "Orthophotography in Architectural Photogrammetry," *E. Seeger (FRG);* "Use of Analytical Plotters in Architectural Photogrammetry," *C. Sena (Italy).*

MAJOR TRENDS IN NON-TOPOGRAPHIC PHOTOGRAMMETRY (1972-1976)

The number of organizations which use photogrammetry in non-topographic applications has increased noticeably over the past four years. Where, previously, work in this area was done primarily in universities and research outfits with an interest in photogrammetry and mapping, there are presently several organizations, including hospitals, government agencies, and private companies, in several countries, which use photogrammetry in non-topographic applications on a more-or-less regular basis, both for production and for research purposes. During the reporting period, rapid technical developments have taken place, together with a substantial increase in conventional applications. Whereas the number of countries in which non-topographic photogrammetry is used has increased over the past four years, there are still numerous countries which have yet to use photogrammetry outside the realm of topographic mapping. Following is a summary of the major trends in the various facets of non-topographic photogrammetry during the period 1972-1976. This information is based, in part, on reports received from 15 National Correspondents of ISP Commission V.

INSTRUMENTATION

Data acquisition equipment. Metric Cameras. The major photogrammetric camera manufacturing companies continued to increase the versatility and flexibility of their close-range and terrestrial cameras, in particular as far as the range of focusing is concerned. Another feature which has been added in response to users' demands is the possibility to use film (roll and/or cut) in addition to the traditional glass plates.

All manufacturers of photogrammetric close-range and terrestrial cameras were requested to identify their new cameras and improvements introduced since 1972. Following is a summary of the information received, arranged alphabetically.

Hasselbald. A number of recent modifications have been made in the production program of the MK70 metric camera. Upon request, the 100mm Planar lens can be obtained

prefocused at any desired distance down to 6 feet. The 80mm *f*/2.8 Planar lens has been deleted from the equipment program. A special tripod coupling has been recently introduced. It eliminates side-play and ensures a good repetition of the camera position after removal and re-installation of the camera.

Jenoptik. The UMK 10/1318 Universal Photogrammetric Camera, which was introduced in 1970, has been redesigned and used as a central unit in a recently developed UMK 10/1318 Universal Photogrammetric Camera System. The system is composed of four basic groups of functional units (metric chambers, magazines, mounts, and electronic gear) which can be optionally combined in four logical combinations. Two versions of the metric chambers are available; type F, equipped with a Lamegon 8/100 lens (*f*/8, f = 100mm), and type N, equipped with a Lamegon 8/100-N lens. The focusing range of both lenses is 1.4m to infinity. The Lamegon 8/100-F lens has distortion less than 12μm for object distances between infinity and 3.6 meters, while the Lamegon 8/100-N lens has distortion less than 12μm for object distances between 1.4 and 4.2m. The range of tilt of the camera axis is between -30° and +90° with clickstops at 15° intervals. The magazine has two basic designs: one for 13cm × 18cm glass plates (version P) and the other (version F) for 190mm roll film. Since both designs can be optionally fitted with a Lamegon-F or a Lamegon-N lens, the system involves altogether four types of cameras: two for film 10/1318FF and 10/1318NF) and two for glass plates (10/1318FP and 10/1318NP). For film flattening, a vacuum back, similar in design to those used in aerial cameras, is used and is connected to an external vacuum system. A plate adapter frame can be attached instead of the film magazine, thus enabling 13 × 18cm glass plates to be used in the film model. Single and double mounts are available.

Wild Heerbrugg. The P31 Universal Terrestrial Camera (f = 100mm, *f*/8, plate format 4in. × 5in. (102mm × 127mm)) was put on the market in 1974 and its focusing range has been recently improved. The P31 is focused at a standard distance of 25m. Sharp images can be obtained for object distances between infinity and 6.5m (for an aperture of *f*/22 and circle of confusion of 0.05mm). With additional precise adapter rings, which can be easily interchanged by the user himself, the camera can now be focused on distances of 7m, 2.5m, 2.1m, 1.8m, 1.6m, and 1.4m. The radial distortion of the lens is less than ±4μm. The P31 operates with 4 in. × 5 in. × 3mm glass plates and has an adapter for cut film.

A most significant improvement to the P31 was announced in July 1975: An interchangeable super-wide-angle lens cone (Wild 4.5 SAgII) was developed for this camera. The new lens has an extremely large depth of field, ranging from 1.5m to infinity for *f*/22 and a circle of confusion of 0.05mm diameter (3.6m to infinity for *f*/5.6 and the same diameter of circle of confusion). The nominal principal distance of the cone is 45mm. Glass plate (cut film) format is 4 in. × 5 in. (102mm × 127mm) and image format is 92mm × 118mm. The radial distortion is within ±4μm, and the resolution (AWAR) at *f*/5.6 and infinite contrast is 70 lines per millimeter. This improtant development was announced for the first time during the ASP Symposium on Close-Range Photogrammetric Systems in Champaign in July 1975 and was enthusiastically received. It is expected that this new addition will be on the market sometime in 1976.

The Wild P32 Terrestrial Camera (f = 64mm, *f*/8, plate format 6.5cm × 9cm, image format 60mm × 80mm), which was put on the market in 1972, can now be mounted on six types of Wild theodolites by means of special adapters (T1A/T1, T16, and T2, both old and new models). All theodolites adapted for the Wild DI-3 also can be used with the P32. A 40cm base bar also has been introduced for use in combination with two P32's, permitting stereoscopic horizontal photographs in the photogrammetric "normal case." The bar has four adapters, making three base lengths possible: 40cm, 30cm, and 20cm. The base bar can be rotated around a vertical axis and locked with a lever. Syncronized release for both P32's is possible.

The focusing range of the P32 also was improved. The P32 has a fixed standard focus at 25m, which permits sharp photographs down to a minimum distance of 3.3m (for *f*/22 and a circle of confusion of 0.05mm diameter). Any change in focus between 25m and 2.5m can be performed at any Wild workshop. If a shorter focusing distance is required, the P32 must be modified at the factory in Heerbrugg. The focusing range then possible is 0.7m to 1.40m. Once this modification has been made, a change of focusing within the range 0.7m to 1.40m, a change to 2.5m or more, and a change back to the range 0.7m to 1.40m can be made in any Wild workshop.

Zeiss (Oberkochen). No modification or new data acquisition instruments were introduced since the Ottawa Congress.

Non-Metric Cameras. Although various types of photogrammetric cameras are presently available, there is a considerable use for "off-the-shelf" non-metric cameras as

indicated in the reports from Canada, Romania, and the U.S.A. The utilization of non-metric cameras for photogrammetric purposes is under study in numerous countries, particularly in Austria, Poland, and Hungary. The use of non-metric cameras in photogrammetric projects has been made possible through the utilization of advanced analytical data reduction techniques. The development of analytical data reduction techniques particularly suitable for non-metric photography has been reported from most countries using or styding the use of such cameras in non-topographic photogrammetric applications.

The following quotation is from the Report of Dr. W. Faig, Chairman of ISP Working Group V/2 (Photogrammetric Potentials of Non-Metric Cameras), to the Helsinki Congress:

> "Concluding, I would like to state that the use of non-metric cameras has expanded within the past four years and has made an impact in a large number of areas where measurements are required. The non-metric camera/computer evaluation combination has reached its fullest potential, and accuracies reaching the photogrammetric noise level have been achieved. It often depends on the individual project, whether the low cost camera/expensive evaluation system or the metric approach is more suitable or financially advantageous, which leaves the decision to the user. Often project arrangements require versatility and light weight which can only be met by non-metric cameras, and with the progress that has been made in the evaluation phase this option now can be a high precision approach. The photogrammetric potentials of non-metric cameras are indeed very high."

It is clear from all reports about the use of non-metric cameras for photogrammetric purposes that such cameras are regarded as a supplement to, rather than replacement of, photogrammetric cameras, and that both types of cameras (metric and non-metric) have an important role to play in the wide spectrum of photogrammetric data acquisition activities. In spite of the ever-increasing flexibility and versatility of commercially available terrestrial and close-range photogrammetric cameras, there are situations in numerous areas of applications (and potential applications) of non-topographic photogrammetry in which the use of metric cameras cannot be justified or is simply not feasible because of technical, environmental, and/or economical constraints. It seems to me that a "metric or none" stand in such cases is completely unjustified, particularly in view of the availability of ways and means to effectively handle non-metric photography.

Understandably, there is resistance to this non-metric trend from photogrammetric equipment manufacturers and from classical photogrammetrists in some countries; however, all indications are that the non-metric tide will continue to rise. The discussions on this topic during the sessions of ISP Working Group V/2 at the Helsinki Congress should be of great interest!

The following non-metric multiband camera system was reported in the American literature in 1975.

Whittlesey Multiband Camera System. This 35mm camera system for aerial archeology was introduced in 1975 by the Whittlesey Foundation. The system is composed of three Rollei 35 cameras, equipped with Zeiss Tessar 40mm focal length lenses. The film advance is motorized and radio-controlled. A capacity of three cameras such as for color, black/white, and infrared, or for various filter combinations, suffices for most archaeological missions. Two cameras in unison will do for many missions, and one will satisfy some. The system weighs 23 pounds and measures 7 × 13 × 1.5 inches.

X-Ray Photogrammetry. Application of X-ray photogrammetry in a wide spectrum of bio-medical research and development efforts was reported from Canada, FRG, France, GDR, Sweden, USA, and USSR. Progress has been reported from Canada, Sweden, and the USA on the development of analytical systems for X-ray photogrammetry and on the refinement of techniques for X-ray photogrammetric measurement of the spine, hip, and knee joints and in orthodontics and dentistry.

Investigations on the use of X-ray photogrammetry in metallurgy was reported from the USA and USSR.

Scanning Electron Microscopy. Work on the calibration of the geometry of SEM for stereophotogrammetric mapping and on the development of methodologies for evaluation of stereomicrographs has been reported in a number of countries including Canada, UK, the USA and USSR.

Optical Contouring Methods. Considerable research efforts in holography, hologrammetry, and Moiré topography are underway in a number of countries including Canada, Japan, UK, USA, and USSR. No direct application of these techniques, has been reported, as yet, in the literature or by the National Correspondents of ISP Commission V, but it is universally believed that coherent optics have the potential to play a number of key roles in a wide variety of non-topographic photogrammetric systems of the future.

Data Reduction Equipment. Two instru-

ments of particular interest to Commission V were introduced since the Ottawa Congress in 1972.

Zeiss G2 Stereocord. This is a simple plotter for computer-supported plotting. It is based on the design of the Zeiss Stereotop and is intended for those areas of application where the high efficiency of precision stereoplotters is not warranted. The analog-mechanical computers of the Stereotop are replaced by an electronic desk calculator (or a minicomputer if the user so desires). The new plotter can be used to plot from aerial, terrestrial, and oblique stereograms. Furthermore, it can be used to plot from single photographs, especially when a perspective grid is superimposed in the picture. In addition to the digital readout of object-space spatial coordinates, it is possible to undertake direct on-line computations of such parameters as distances, differences in elevation, slopes, direction angles, areas, and volumes, and to perform statistical evaluation of these parameters.

The Micro Surfer (also known as EMPD) of Cartographic Engineering Ltd., England. This instrument has been specifically designed for the three-dimensional analysis of scanning photo-micrographs. Stereo pairs of micrographs taken at a known tilt angle, normally 10°, are inserted in the instrument which can accept any size micrographs up to 4 in. × 5 in. It is designed for either contact prints or transparencies. These are observed with stereo optics at 2X magnification. A balanced lever attachment moves the photographs with respect to the stationery floating mark. The X-parallaxes are measured and directly formulated to give height differences. The contours and profiles are plotted at twice the photographic magnification. Vertical and horizontal measurements are limited only by the SEM resolution. A relatively unskilled operator can operate this rather simple plotter. The Micro Surfer was developed on the ideas of Professor A. Boyde, of the University College London.

DATA REDUCTION TECHNIQUES

Both single-image and stereoscopic approaches to photogrammetry were featured in the reports of the National Correspondents of Commission V. Considerable use is made of single-image photogrammetry in Austria where the light slit image method *(Lichtschnittverfahren)* is extensively used in profiling and cross-sectioning of railroad, highway, and street tunnels. Single-image photogrammetric measurement of the optic disc were made in Sweden by using the slit image method. Single-image photogrammetry was also applied in Sweden to athletic contests, and used in Hungary in a wide variety of projects.

One of the major trends in the development of non-topographic photogrammetry during the past four years has been the increasing use of analytical data reduction methods, as reported from Austria, Canada, Czechoslovakia, Finland, France, Hungary, Norway, Romania, South Africa, Sweden, the USA, and USSR. With little modification, many of the computational methods which were developed over the years for aerial mapping and aerotriangulation can be applied in non-topographic projects.

Through the use of advanced analytical data reduction techniques, the use of non-metric cameras for data acquisition in close-range and micro-range photogrammetry has become possible. A number of analytical data reduction approaches, particularly suitable for non-metric photography, have evolved; the Direct Linear Transformation (DTL) approach developed in the USA is a case in point. On-the-job calibration approaches and self calibration methods are widely used in connection with non-metric photography, as reported from Austria, Canada, Hungary, Poland, Romania, and the USA.

The use of advanced analytical data reduction techniques also makes it feasible to solve some non-topographic problems satisfactorily by utilizing simple photogrammetric equipment (mirror stereoscope, parallax bar, etc.), as reported from Sweden.

In applications where the point-by-point approach inherent in the analytical solution is not acceptable (e.g., in some aspects of architectural photogrammetry), the use of analytical plotters combines in a most favorable way the advantages of both the analogue and analytical evaluations. Experiments are being carried out in Canada and Italy to evaluate the advantages of analytical plotters in non-topographic photogrammetry, particularly in conjunction with architectural surveys. Analytical plotters also are used in Canada for data reduction from non-metric photography.

In many areas of application of non-topographic photogrammetry, a digital model of the surface being mapped is often a more desirable product than the conventional contour map on account of its flexibility, whether one is interested in measuring the surface geometry or in evaluating the deformations and movement of objects. A digital model provides the user with almost unlimited flexibility in the use of the electronic computer for design and analysis. Mathematical model-

ing of a surface and its behavior can be performed conveniently by using a digital model. Such parameters as surface area and volume as well as deformation of the surface and velocity and acceleration of surface points all can be computed directly from the digital model(s). Progress in this direction was reported from Canada, France, Norway, Sweden, the USA, and USSR. Analytical methods have been developed to generate contours, cross-sections, profiles, and perspective views directly from digital data.

Naturally, the analog and semi-analytical approaches to data reduction continue to be used in different applications in all reporting countries.

AREAS OF APPLICATION

Architectural photogrammetry. Considerable increase in the volume of activities in architectural photogrammetry and the development of new methods and techniques characterized the reporting period. Austria, Canada, Belgium, Czechoslovakia, France, Hungary, Norway, Poland, South Africa, the UK, and USSR were among the countries reporting significant increases in recording of historical items and sites. While historic castles, cathedrals, altars, national shrines, battle-fields, defense installations, and other important buildings and grounds are subjects for photogrammetric documentation in most reqorting countries, the recording of the wealth of fast-deteriorating cave paintings and rock engravings of the Bushmen are among the unique features of the archeological photogrammetric activities in South Africa. Also, work is underway in Canada and the USA on the restoration of Indian villages and pueblos, using photogrammetry to document these historic items and sites and to prepare restoration drawings. In Sweden, applications to archeology include photogrammetric measurement of prehistoric boat findings and sunken vessels.

The expansion in architectural photogrammetric activities was accompanied by the development of new techniques and methodologies. The application of orthophotography to the documentation of facades of buildings and monuments was reported from Poland the Federal Republic of Germany (FRG), while Austria reported the use of analytical block triangulation for facade documentation. Experiments with underwater analytical block triangulation were undertaken in Sweden in connection with photogrammetric measurement of sunken vessels.

The use of digital models and the deduction of any desired view of entire urban quarters to help planning against visual pollution was reported from France, the USA, and USSR. Experiments are underway, particularly in Canada and Italy, to evaluate the advantages of analytical plotters in architectural surveys.

In France, helicopters are widely used for large scale (1/500 to 1/2000) surveys of historical items and sites as well as in conjunction with periodic control surveys in geologically unstable areas and for the measurements of large radio antennas. In Hungary extensive surveys of roof surfaces are conducted by aerial photogrammetry.

Biomedical photogrammetry (biostereometrics). One of the most significant developments during the past four years has been the rapid increase in the use of photogrammetric techniques in biomedical research and clinical medicine, as reported from numerous countries including Canada, Finland, France, Hungary, Poland, Romania, South Africa, Sweden, the UK, USA, and USSR. This fast-growing field, referred to sometings as "biostereometrics", is fully expected to continue to increase in importance. Studies in cranio-facial morphology, including facial surgery, ophthalmology, dentistry, and orthodontics were reported from Canada, Finland, South Africa, Sweden, UK, the USA, and USSR, while various spatio-temporal (4D) anthropometric studies were reported from Canada, Hungary, the USA, and USSR. Studies in stereometric X-rays were reported from Canada, FRG, Hungary, Sweden, USA, and USSR, and various studies and projects involving the determination of body geometry and form were reported from Canada, France, Hungary, Romania, South Africa, Sweden, the UK, USA, and USSR. Biomedical studies connected with space flights were conducted by using photogrammetry in the USA and USSR. In the USSR, investigations were made on the positions of eyeballs of cosmonauts in orbit, while one of the US studies dealt with the effects of extended space flights on the body forms of Skylab astronauts.

Industrial photogrammetry. The vast field which is generally referred to as "industrial photogrammetry" (encompassing the application of photogrammetry in building construction, civil engineering, mining, vehicle and machine construction, metallurgy, shipbuilding, and traffic, with their fundamentals and border subjects, including the phases of research, planning, production engineering, manufacture, testing, monitoring, repair, and reconstruction) has undergone significant

growth and progress during the past four years.

The use of photogrammetry in measuring pertinent dimensions of car body models in order to obtain production data was reported in the Italian and East German (GDR) literature. Machine construction, metal working, and quality control are areas in which photogrammetry has been used in GDR, the USA, and USSR.

Austria, Canada, Czechoslovakia, Finland, France, Hungary, Poland, Romania, South Africa, Sweden, the UK, USA, and USSR reported using photogrammetry in one facet or another of mining engineering, e.g., in process measurement in open pit mining, tunnel cross-sectioning and profiling, geological measurements, rock deformations, rock mechanics investigations, monitoring of products in mines, etc.

In Austria, Canada, Poland, Romania, South Africa, Sweden, the USA, and USSR, photogrammetric studies of objects in motion for a wide variety of purposes were reported. This category includes tracking hand motions in industrial operations, studying glacier movements, assessing deformations of aerodynamic models in wind tunnels, tracking of particle flow in bubble chambers, and evaluation of displacements caused by explosions, etc.

In Belgium, Canada, Norway, South Africa, Sweden, the UK, USA, and the USSR, photogrammetry is used in the shipbuilding industry, including some or all of the following aspects: measurement of ship sections, measurement of ship propellers in various stages of fabrication, wave measurements, and position determination in model experiments, etc.

The use of photogrammetry in connection with structures and buildings, e.g., to check on the construction and/or to measure deformations of chimneys, buildings, experimental structural models, and/or large structures such as antenna reflectors and power dams, were reported from Austria, Belgium, Canada, Czechoslovakia, Finland, France, Hungary, Norway, Poland, Romania, South Africa, Sweden, the UK, USA, and USSR.

Austria, Canada, Romania, Sweden, UK, the USA, and USSR reported using photogrammetry in one aspect or another of traffic engineering, e.g., in traffic accident investigations, profiling and cross-sectioning of roads and traffic tunnels, road surface roughness studies, ship path determination, etc.

Other miscellaneous industrial applications reported include studies of stability of dump sites (Belgium, Poland, South Africa, USSR), soil erosion studies (Poland, South Africa, the UK, USA, USSR), underwater mapping (Poland, South Africa, Sweden, USA, USSR), forest economic studies including the classification of growing trees (Austria, Sweden), the determination of sagging of powerlines under weight of freezing rain (Canada), evaluation of fishing equipment (USSR), and estimation of food-fish resources (USSR).

Concluding Remarks

During the period 1972-1976, significant progress was made in various aspects of non-topographic photogrammetry including:

- substantial increase in new fields of applications, particularly in biomedical and industrial photogrammetry, and a significant increase in the volume of activities in architectural photogrammetry;
- development of new data reduction techniques (mainly analytical) and the refinement of established approaches;
- significant increase in the flexibility and versatility of close-range and terrestrial metric cameras; and
- opening the door for the use of small-format non-metric cameras in non-topographic photogrammetry by the development of data reduction techniques particularly suitable for non-metric photography; and the gradual acceptance of such cameras as data acquisition tools, along with metric cameras, thus broadening the range of cameras available for non-topographic applications.

All indications are that the progress achived during the past four years will continue at an even faster rate, and that great strides will be made in all facets of non-topographic photogrammetry in the immediate and near future.

Acknowledgments

This report is based, in part, on reports received from the National Correspondents of ISP Commission V in the following countries: Austria (K. Hubeny), Belgium (F. Camps), Canada (M.C. van Wijk), Czechoslovakia (Z. Marsik), Finland (P. Martimo), France (P. Hottier), Hungary (M. Domokos), Norway (O. Øfsti), Poland (Z. Sitek), Romania (A. Gutu), South Africa (K.N. Greggor), Sweden (K. Torlegård), U.K. (K.B. Atkinson), U.S.A. (K.W. Wong), and the U.S.S.R. (V.K. L'vov). The cooperation and valuable contributions of these colleagues are sincerely appreciated and gratefully acknowledged.