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Working Group 2

Working Group Report

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THE ACTIVITIES OF THE WORKING GROUP ON IMAGE GEOMETRY BETWEEN 1972 AND 1980

Abstract:

The activities of the Working Group on Image Geometry (WG I/2) of Commission I are reviewed. The report deals with the formation of the WG and the organization and execution of the chosen project, the demonstration and comparison of different procedures for the determination of lens distortion, and the use of these procedures to determine two-dimensional (x,y) overall lens distortion values. All practical work was carried out on two cameras equipped with a front-projected réseau.
The report does not include technical results.

DIE AKTIVITÄTEN DER ARBEITSGRUPPE BILDGEOMETRIE ZWISCHEN 1972 AND 1980

Zusammenfassung:

Ein Überblick wird über die Aktivitäten der Arbeitsgruppe Bildgeometrie gegeben. Der Bericht behandelt die Bildung der Arbeitsgruppe und die Organisation und Durchführung des gewählten Projektes: Demonstration und Vergleich verschiedener Verfahren für die Bestimmung der Objektivverzeichnung und die Benutzung dieser Verfahren für die Bestimmung zweidimensionaler (x,y) Gesamtverzeichnungswerte. Alle praktischen Arbeiten wurden an zwei mit einem als Teil des Abbildungsstrahlenganges projizierten Réseau

ausgerüsteten Luftbildkammern durchgeführt.
Der Bericht enthält keine technischen Ergebnisse.

LES ACTIVITÉS DU GROUPE DE TRAVAIL SUR LA GÉOMETRIE DE L'IMAGE DE 1972 À 1980

Résumé:

On révise les activités du groupe de travail sur la géometrie de l'image de la Commission I. Le rapport traite de la formation du groupe et de l'organisation et éxécution du projet choisi: la démonstration et la comparaison de différentes procédures pour la détermination des distortions de lentilles et l'usage de ces procédures pour la détermination en deux dimension (x,y) des valeurs de la distortion totale de la lentille. Tout le travail pratique a été éxécuté avec deux appareils de prises de vues équippés de réseau projeté à l'avant.
Le rapport ne parle pas des résultats techniques.

1. INTRODUCTION

During initial discussions between Dr. Blachut, then head of the Photogrammetric Research section of the National Research Council of Canada (NRC), and Dr. E. P. Welander, the newly assigned president of Commission I, at the Ottawa congress, Dr. Blachut offered that NRC would be willing to organize a working group (WG) to be established in accordance with resolution I/3 which read

> Commission I recommends the formation of a working group on image geometry, with consideration for relevant liaison with the other commissions, particularly III, V and II. It is recommended, as a continuation of past efforts to calibrate individual components of the system, that one of the tasks of this working group be oriented towards the evaluation of calibration procedures for entire photogrammetric data acquisition systems. Another task to be considered would be metric experiments with side-looking radar.

Dr. Welander invited H. Ziemann in a letter dated 1972-12-15 to organize and chair the new WG. Shortly after, in a letter dated 1973-01-09, H. Ziemann invited D. C. Merchant to become co-chairman. It was hoped at that time that close cooperation could be established with the OTF/MTF WG of Commission I and with Commission III; neither materialized to any appreciable extent, although contact was kept to Mrs. C. L. Norton, the chairlady of the OTF/MTF WG throughout. Also, the last sentence of the cited resolution led to the formation of a different WG dealing with remote sensing systems. This WG was organized and is still chaired by Prof. Dr. G. Konecny of Hannover University. It became attached to Commission III primarily because that commission was hosted at that time by the Federal Republic of Germany. Dr. Welander formally accepted this development in a letter dated 1973-06-29.

After informal discussions, a literature review and some correspondence, the following desirable program, placing emphasis on camera and system calibration problems, crystallized in February

1973, to be carried out on two réseau cameras available at the Department of Geodetic Science of The Ohio State University in Columbus Ohio, (U.S.A.) - a Zeiss RMK camera with the Pleogon-AR-5.6/153 lens cone no. 98222 - and at the Photogrammetric Research section of NRC in Ottawa (Ontario, Canada) - a Wild RC5/RC8 camera with the Universal-Aviogon-5.6/153 lens cone no. 15 UAg R-10:

1. camera calibrator with a single bank of collimators
2. camera calibrator with several banks of collimators
3. horizontal goniometer
4. vertical goniometer
5. Itek Artificial Stellar Calibrator using several wave lengths and different camera positions
6. stellar calibration using a tracking camera
7. stellar calibration using a fixed camera
8. system calibration over a flat test area using photographs with the same scale
9. system calibration over a flat test area using photographs with at least two distinctly different scales
10. system calibration over a flat test area combining vertical and oblique photographs
11. system calibration over a test area with significant height differences (method of mixed ranges)
12. system calibration over a test area combined with the determination of the exposure stations

After visits to the Institutes of Photogrammetry of Bonn University and Helsinki University of Technology (where members of the photogrammetric staff of the Technical Research Center of Finland were also met), Wild Heerbrugg Ltd., Carl Zeiss Oberkochen, the board of Commission I in Stockholm, 75 letters and 4 telex messages, not counting phone calls and contacts between WG members, the intended program had been confirmed with the following number of contributions: 1-1, 2-1, 3-2, 4-1, 5-3 (3 positions, 1 wave length), 6-0, 7-2, 8-4 (in combination with 9), 9-4, 10-1 (in combination with 9), 11-0 and 12-0. Scheduling of the first few steps of the program could now be finalized.

Eighteen pieces of correspondance dealt also with the provision of a person accompanying the cameras on their journey to observe adherence to the schedule, help in mounting and operating the cameras, assist in customs procedures and set up vibration determination equipment. Although we found a willing candidate, we were unable to secure his services. Later difficulties underlined the importance of having such a person.

It was also established during the early stages of the program that the manufacturers were unable within the given time frame to modify their equipment to accomodate the other manufacturer's camera for lens distortion measurements.

Attempts to include the new Universal-Aviogon-II-f/4 cone which is also equipped with a front-projected réseau, and to coordinate the testing of that cone with at least part of the program of the WG failed unfortunately. Results achieved with this cone have in the meantime been published by L. W. Fritz and C. C. Slama, two members of the WG.

The goniometer at Helsinki University of Technology was modified,

as a result of a visit, to enable the determination of tangential lens distortion /Hakkarainen 1976c/.

The desirability to also determine image quality became soon apparent. Therefore, optical and modulation transfer functions were determined. These data will eventually help to derive correlations between image point locations and image quality.

The new board of Commission I, awarded during the Helsinki congress to the Japan Society of Photogrammetry, formally announced the continuation of the WG as "WG on Image Geometry with Camera Calibration" in their letter dated 1976-12-15.

The following report gives an overview over the activities of the WG during the period 1973 to 1980, divided into six sections: initial data acquisition and camera shipping, mensuration of calibration plates and test area photographs, processing of measurements, WG meeting and symposia and congress participation, publication of results, and participating agencies and the financing of the project.

2. INITIAL DATA ACQUISITION AND CAMERA SHIPPING

The RMK arrived in Ottawa on 1974-02-21. Plates were taken with the NRC camera calibrator /Carman and Brown 1978/ for both cameras on 1974-03-04. This equipment had been modified to enable controlled rotation not only between the exposures of the two format diagonals but also between additional lines placed 10 gon (9^{o}) apart.

The Itek Artificial Stellar Calibrator and specially built camera mounting equipment were sent from Itek Corporation's Palo Alto plant by air cargo to Ottawa on 1974-03-02. The equipment arrived in Ottawa only on 1974-03-08: it had been misplaced during an air line transfer, and was located only after five days of intensive telephone operations. In order to be able to use it at all, it had to be picked up personally in Montreal. The equipment arrived in Ottawa on a Friday evening and had to leave the following Sunday morning for an exhibition in St. Louis; hence, all desired plates had to be taken within 36 hours. Since the coverage of the full 23cm by 23cm format required 5 exposures, and since exposures were taken in three different camera positions, 5 · 3 · 2 exposures needed to be made in that time. These exposures were all done with the same-wave-length-HeNe-laser light source. An additional wave length would have doubled the number of exposures. All plates were flattened with the NRC plate flattener; this was the reason for bringing the Itek equipment to Ottawa. Because of time pressure, test exposures were made only for the first exposure with the result that the quality of the recorded images left in some of the following exposures much to be desired. The poor quality of a relatively large number of point images is one of the reasons why the Itek Artificial Stellar Calibrator data still await final processing at this time.

On 1974-03-13, the cameras were shipped to Lahr, Germany, by a Canadian Forces aircraft on a regular supply flight from near Toronto, to where they had been brought by car. the cameras were picked up by truck and brought directly to Oberkochen on 1974-03-15, after a misunderstanding led to the empty return of the

truck to Oberkochen the day before. The RC8 was forwarded directly to Heerbrugg, where it was to undergo also an operational modification. After completion of the calibration in Oberkochen, the RMK was brought to the Institute of Photogrammetry in Bonn on 1974-04-29, and was awaiting there the arrival of the RC8 on 1974-05-03, at which time both cameras were forwarded for installation into an aircraft in preparation of photography over the Rheidt test area. This photography was taken on 1974-05-13. An attempt to repeat the test area photography with a different type of aircraft was only partially successful on 1974-05-30.

In the meantime, the projected most favourable flying time in Finland had been missed as a result of the delay of almost three weeks in the project schedule, and the late Prof. Dr. Halonen became very upset about this. The cameras finally arrived in Finland on 1974-06-05. A fixed vacation schedule at Helsinki University of Technology reduced the time available in Helsinki to about four weeks. During this time, the Jämijärvi and Seglinge test areas were flown, and about half of the intended goniometer measurements could be carried out. The cameras were sent to the Physical Technical Federal Institute in Braunschweig in early July for OTF measurements. Since the cameras had to leave Braunschweig again on 1974-08-23, the time available for measurements was, as a result of interfering vacation schedules, very short, and modifications to enable rotation of the lens cones to measure along the format diagonals could not be made. Hence, OTF measurements were carried out along the lines connecting the format middles. It was unfortunate, that the determinations could not be carried to the format corners where image quality is poorest, in particular in view of determining the correlation between image quality and image point location, but the results proved nonetheless extremely valuable in comparison with other OTF and MTF data. H. Ziemann visited the Physical Technical Federal Institute on his way to the Stockholm symposium and transported the cameras by rented truck to Lahr, from where they were returned to Canada again on a regular flight by a Canadian Forces aircraft on 1974-08-25.

Upon return of the cameras to Canada, additional plates were exposed on the NRC camera calibrator on 1974-09-15. At the same time, final arrangements were made for aerial photography over the Sudbury test area. Tenders had been called several months earlier. The desired vertical photographs were taken on 1974-09-30, at which date unsuitable oblique photographs were also taken. Oblique photographs confirming closer to the given specifications resulted from another flight on 1974-10-08.

The cameras were shipped for another laboratory calibration to the U.S. Geological Survey in Reston, Virginia, on 1974-10-11. Extensive experimentation directed towards exposure of the réseau took place there. Because of scheduling constraints imposed by the phase of the moon, the cameras were transfered prior to taking satisfactory plates at the U.S. Geological Survey, to the National Ocean Survey in Rockville, Maryland, for stellar calibration. Their set-up accepted the RC8 readily, and plates were taken on 1974-10-21 and 22. Afterwards, the set-up was modified as required for the RMK, and plates were taken on 1974-11-08 and 10. The cameras were then returned to the U.S. Geological Survey, were acceptable plates were finally obtained on 1975-01-

31 for the RMK and on 1975-02-03 for the RC8. However, attempts to properly image the entire réseau failed.

The National Research Council received an informal request about the availability of the RC8 for test photography in Mexico during the fall of 1974. After several exchanges of letters between NRC and the national Mexican mapping agency and unsuccessful attemts to have a manufacturer provide the desired réseau camera, a formal request for the camera dated 1975-01-24 was sent to the U.S. Geological Survey, from where the RC8 was shipped to Mexico in February 1975, supposedly for one month. It returned only several months later. The RMK had been sent to Columbus to await the return of the RC8.

Both cameras were brought from Columbus to the Wright Patterson Air Force Base for OTF measurements. From there, they were shipped to DBA Systems Inc. (now Geodetic Services Inc.) in Indialantic, Florida, for another stellar calibration. The required plates were exposed on 1975-09-04, and the cameras were returned to Columbus and from there again to Ottawa. Another set of calibration plates was finally taken in Ottawa on 1976-10-28. The delay in taking these plates was, at least in part, the result of efforts to improve the procedures, since the processing of the previously taken two sets of plates had indicated several unexpected problems associated with exposing 20 lines of collimator images per plate. Since this non-standard procedure had not been used before, a considerable period of time passed until a meaningful explanation could be found and the sources of the problems be eliminated.

The data collection requiring the availability of the cameras took not the expected 6 to 8 months but two years and 6 months! The RMK was finally returned to Columbus on 1977-05-02. During the duration of the camera shipping operations, over 200 additional pieces of correspondence arrived in or departed from Ottawa.

3. MENSURATION OF CALIBRATION PLATES AND TEST AREA PHOTOGRAPHS

Although most procedures for processing the data were not finalized at that time, photograph positions over test fields and points to be measured in the goniometers were specified very early in the project. Also specified was that the réseau be exposed in all photographic laboratory and stellar calibrations, and the numbering scheme for the réseau points.

Time constraints led to goniometer measurements falling short of the specified desired amount: Wild and Zeiss omitted the mensuration of tangential distortion values, Helsinki University of Technology measured radial lens distortion values in only about half the specified points and tangential values in even fewer, but strategically well placed, points. The results from the goniometer measurements were rather soon available and were received in Ottawa on 1975-04-07, 1974-07-15 (in the form of averaged data only) and 1975-03-22 respectively. They were also the first lens distortion data generated by the WG, to be published.

The calibration plates taken in Ottawa, two on the NRC calibrator on 1974-03-04, 18 with the Itek Artificial Stellar Calibrator on 1974-03-09 and two on the NRC calibrator on 1974-09-15,

were measured during the months June to October 1975, mostly by an inexperienced student hired especially for this job, because regular technical staff could not be made available for these measurements to the required extent. The measurements for one complete set of plates taken with the Itek Artificial Stellar Calibrator (6 plates, 4 of these with double exposures in diametral opposite corners), checked for reading and point identification errors, were mailed to Itek Corporation's Lexington, Massachusetts, plant on 1975-08-08, where rather extensive but unsuccessful processing took place. The respective plates were also shipped to Lexington on 1976-06-22 in order to expedite processing, but neither time nor computational funds were available in a sufficient amount to complete the processing of the two calibrations, one for each camera. The material has now been returned.

Calibration plates taken outside Ottawa were not made available to NRC for mensuration with the exception of a few discarded plates taken at the U.S. Geological Survey. These plates feature a single exposure only, and not the triple exposure used at that organization for a calibration /Tayman 1978/. Measurements in the form of listings were made available by the National Ocean Survey in early October 1978 and by the U.S. Geological Survey in mid-October 1979, both times during personal visits. Réseau data are available only from the National Ocean Survey; neither the U.S. Geological Survey nor DBA Systems Inc. succeeded in exposing but a few réseau crosses close to the conventional fiducial mark locations.

Vertical test area photography had been requested in the form of a block of 3 by 3 photographs with 60% forward overlap and 60% side overlap just covering the test area, to be overflown in such a way that the entire test area would appear on each of four photographs flown in the four possible orientations. The photographs were to be taken with both cameras simultaneously on film provided by NRC. The used films were all of the same production run; each film had been divided into two halves of equal length in order that identical film was used for simultaneous exposures. The Jämijärvi, Rheidt and Seglinge test areas are all about 2 km by 2 km large; hence, scales of 1:5500 and 1:10000 were intended. The Sudbury test area is 5 km by 3 km large; a section 3 km by 3 km large was used, and scales of 1:8000 and 1:15000 were intended. All films were sent to Ottawa after processing for the production of the desired diapositives and were returned to the participating agencies afterwards for the production of additional diapositives and retention. The photography over the Jämijärvi, Seglinge and Sudbury test areas conforms with the specifications. Additional photographs were taken over the Rheidt test area: the 3 by 3 blocks were enlarged to 5 by 5 blocks by adding one line of photographs all around the smaller block, the smaller scale exposures were extended into strips. One set of diapositives of the RMK photographs over the Rheidt test area was also produced for the Department of Geodetic Science of The Ohio State University and mailed there.

An attempt to secure small scale photography over the Arizona test area of the U.S. Geological Survey failed.

The larger scale Jämijärvi test area photographs were measured

at NRC in Ottawa between 1974-10-01 and 1975-05-30, with an interruption from 1974-12-16 to 1975-01-30 during which time the smaller scale Rheidt test area photographs were measured. The measurements for the larger scale Jämijärvi RMK photographs were mailed on 1975-06-16 to DBA Systems Inc. for experimental processing but seem to have been lost prior to processing. The smaller scale Rheidt test area photographs were used by a visitor to NRC for a seperate investigation /Bujakiewicz 1976/ which was initially somewhat hampered by the inavailability of test area coordinates; approximate coordinates were received on 1975-01-28 and final coordinates on 1975-03-17, only two months prior to the visitor's departure. Mensuration of test area photographs resumed on 1975-11-21 and continued with short interruptions until 1976-09-28, first with the larger scale Sudbury test area photographs, followed by the smaller scale Jämijärvi test area photographs and then the smaller scale Sudbury test area photographs. Readings for the smaller scale Jämijärvi test area photographs were received on 1976-03-04 from the Technical Research Center of Finland with a note saying that mensuration of the test area photographs could not continue at that institution. All targeted points but only a few réseau points had been measured. It was decided, therefore, to also measure these photographs at NRC. The Finnish measurements proved valuable in expediting these measurements. A magnetic tape with all measurements carried out at the Institute of Photogrammetry of Bonn University was received in Ottawa on 1977-07-20. From these readings were extracted those for 15 of the 18 larger scale photographs. In an attempt to form better blocks, the other three had been replaced by two photographs each. The missing three photographs were measured at NRC. The measurements for the smaller scale photographs were not extracted because not all réseau points had been read at Bonn but had been read during earlier measurements at NRC. Although the two sets of measurements available for the Rheidt test area are not uniform, because two different types of diapositives were measured, this is of no concern since the réseau will permit the elimination of the resulting differences. The Bonn measurements took place between 1977-01-25 and 1977-03-15 (for the extracted data), those in Ottawa for the other three plates in August 1977. The diapositives sent to Columbus were also measured and used by a graduate student /Jiwalai 1977/.

None of the Seglinge photographs has been measured until now.

Only preliminary measurements were carried out thus far on the oblique photographs taken over the Sudbury test area.

All measurements in Ottawa were carried out on a Zeiss PSK I stereocomparator used most of the time as monocomparator; so were the measurements in Bonn and Columbus. All réseau crosses and all targeted test area points were measured in Ottawa twice, all collimator target images four times and all Itek ASC images twice. All points measured in Bonn were read twice as well.

OTF and MTF measurements were arranged through this WG, and the results collected and sent to Mrs. C.L. Norton, chairlady of the OTF/MTF WG. Copies of the OTF data recorded automatically with the Eros IV equipment at the Physical Technical Institute in Braunschweig were received on 1974-08-22, final curves derived from these raw data and additional data attained in Braunschweig

with a different procedure, were received on 1974-12-20. Resolving power and MTF data determined at the Institute of Photogrammetry of Helsinki University of Technology were received on 1975-03-22. The data attained at the Air Force Avionics Laboratory at Wright Patterson Air Force Base were received, already in the form of formal papers, on 1976-05-17. One of these papers presented results from direct OTF measurements /Martin 1977/, the other results derived from the evaluation of photographs simultaneously taken with the two réseau cameras near Ottawa /Gliatti 1976/. These photographs had been sent to Mrs. Norton on 1974-02-26, and from there to the base some time later.

4. PROCESSING OF THE MEASUREMENTS

All measurements were subject to several steps of initial processing. The comparator output was first run through a testing program which verified the validity of the recorded characters, determined reading differences and marked those exceeding 10 µm. The marked points were read once more, and all three readings averaged unless pointing or point numbering errors were found. Only then was the plate removed from the comparator.

Reading differences and histograms for the reading differences were then plotted seperately for réseau and targeted points or collimator target images; this served at the same time as a verification procedure for the automatic numbering of the réseau points. Then, the functional relationship between pointing accuracy and radial distance from the image format center was computed and printer-plotted; this served as as indication for improper placing of plate or film into the image plane. The deformation of each photograph as determined from the réseau measurements is also plotted to identify réseau point mis-identifications which occur in low contrast areas as a result of mistaking the PSK grid lines as part of réseau crosses. Single photograph spatial resections permitted not only the determination of good approximate exterior orientation data for each exposure but also served to identify wrongly numbered or wrongly identified targeted points; they proved also valuable in reconciling the different coordinate systems used by WG members inspite of efforts to avoid this - calibration procedures used by these members required the use of their standard image coordinate system. All described operations followed rather soon after the completion of the measurements and provided data free from gross errors.

The goniometer readings provided by Wild Heerbrugg and Helsinki University of Technology were treated the same way to the extent possible. Carl Zeiss Oberkochen did not provide the original readings.

The design of the cone no. 15 UAg R-10 permits removal and remounting into the same position, of the réseau plate (to enable cleaning of both sides) without changing adjustment and calibration of the cone. Hence, Wild Heerbrugg were able to provide comparator readings for the positions of the réseau points used as images for the goniometer calibration also.

In preparation for the refinement of the measured coordinates for targeted point images and collimator target images to be carried out by least square interpolation, correlation function

data were determined in a next processing step from the réseau measurements. All these computations were carried out in October 1978 at the U.S. Geological Survey in order to conserve some of the always sparse computational funds at NRC. Once before, in early 1976, the Photogrammetric Research section ran out of computational funds all together, thereby stalling this project.

Some of the measurements were further processed to a more final result /Ziemann 1978a, b/ in addition to the standard processing carried out in Heerbrugg, Helsinki, Oberkochen and Ottawa using a procedure which first transformed the given réseau point locations and object space angles in such a way that spatial resections could be computed. Results obtained from standard processing were published in /Carman and Brown 1978/ and /Hakkarainen 1976a/.

Mensuration and processing of the stellar calibration plates taken at the National Ocean Survey and at DBA Systems Inc. has been described in /Fritz and Slama 1976/ and in /Strahle 1975/ respectively, mensuration and processing of the plates taken at the U.S. Geological Survey equipment in /Tayman 1978/. None of these data have as yet been processed in the same manner as the goniometer data and the NRC calibrator data.

The smaller scale Rheidt test area photographs were processed at NRC within a small research project to test the suitability of polynomials to effectively correct lens distortion /Bujakiewicz 1976/. The larger scale RMK Rheidt test area photographs were processed, as 5 by 5 block, in Columbus in an investigation designed to compare the equivalence of various sets of interior orientation and lens distortion data as provided by WG members prior to October 1976 /Jiwalai 1977, Merchant 1977/. Funding for this investigation had been received from the United States National Science Foundation; part of these funds enabled D.C. Merchant to attend the Helsinki congress.

The Rheidt test area photographs, primarily those at the smaller scale, were also processed in Bonn, where investigations attempted to show the effectiveness of lens distortion correction and film deformation correction by means of the réseau, and to demonstrate the merits of a system calibration over a test field as compared to self calibration by means of additional parameters in a bundle adjustment. The lens distortion data used in Bonn were supplied from NRC in March 1975. They were at the time the only data available for each réseau point but resulted from calibrations carried out prior to the commencement of the WG project, namely in 1971. Results of the Bonn investigations are included in /Ellenbeck 1976a, Ellenbeck and Kupfer 1978, Kupfer 1976 and Kupfer 1978/.

Not much progress has been made in the processing of the Sudbury and Jämijärvi test area photographs, and in the comparable processing of the Rheidt test area photographs, the stellar calibration data, the U.S. Geological Survey data and the Itek ASC data for the following reasons:

- suitable calibration software. It was realized after discussions with several WG members that software is required which permits the processing of all the different types of data with due regard to their special characteristics.

- time to prepare software. It was also realized that the preparation of such software required undivided effort. This was one of the reasons for H. Ziemann's request for a leave-of-absense from NRC to work for one year at the Institute of Photogrammetry at Bonn University, after an invitation from the director of that institute, Prof. Dr. G. Kupfer.
- adjusted Sudbury test area ground control. The Sudbury test area was established by the Photogrammetric Research section between 1965 and 1969 and has been maintained since. It had not been intended for extremely-high-accuracy experiments; hence, the measurements were never subjected to a simultaneous adjustment. After recognizing this fact, H. Ziemann started in 1976 with preparations for such an adjustment. This work proved to be demanding on working time and on computational funds and has not yet been completed. Corrections for the point positions were derived in October 1979 which may have led to corrected coordinates final to the millimeter, but a simultaneous adjustment of all levelling data remains to be carried out.
- computational funds. They were short practically all the time, and were another reason for accepting the invitation to Bonn.
- manpower. Technical support for the project at NRC was always sparse as well, to the extent that H. Ziemann carried out a significant amount of the measurements himself.

The preparation of suitable software to handle the determintion of interior orientation parameters inclusive polynomials for radially symmetrical and decentering distortions, from the different sets of data with due regard to the special characteristics of these data will be completed shortly. At this time, the actual processing will commence. It is hoped that most of the processing for the measurements now in hand can be completed prior to the Hamburg congress.

5. WG MEETING, AND SYMPOSIA AND CONGRESS PARTICIPATION

It was soon realized that a meeting of the WG should be held to "provide a forum for the presentation and discussion of results" (memo dated 1975-01-20), although not all intended calibrations had been confirmed at that time, and although it was already foreseeable at that time that the WG project would not be completed in time for the Helsinki congress. A circular letter dated 1975-02-13 announced the meeting with a choice of two possible dates (prior and after the semi-annual meeting of the Americam Society of Photogrammetry, to enable European WG meeting participants the attendance of that meeting). A following circular letter was mailed on 1975-08-29 with the following enclosures:

- a tentative program
- a map showing the two buildings where the meeting took place
- a map of the vicinity of NRC showing motels, restaurants and gas stations, especially prepared for this meeting
- two business cards for the nearest two motels
- a smaller scale map showing NRC and also the downtown area
- an index map for all bus routes in the Ottawa area
- a letter from the editor of Photogrammetria giving a deadline for submission to enable publication of papers prior to the Helsinki congress

- Photogrammetria's Note to Contributors
- submission details for presented papers for the Helsinki congress

The final meeting date had been determined earlier based on feedback from WG members, and had been announced via a meeting announcement. In addition, 69 letters, 13 telex messages and 8 internal memos were received in or mailed from Ottawa in preparation of the meeting, not counting the mailing of the announcement of the meeting to a large number of addressees, and a bank account was opened prior to the WG meeting on 1975-10-22. The meeting was attended by 16 of, at the time, 19 WG members and by 13 additional persons. A reception was organized with the help of the Ottawa Branch of The Canadian Institute of Surveying. The National Research Council provided $ 2400 in travelling support funds which were divided between participating WG members representing universities and government organizations. These travelling support contributions proved to be extremely valuable in enabling so large a number of WG members their participation in the meeting.

The meeting provided a forum for open discussions about attained results and problems encountered with the different calibration procedures. It had been hoped to receive a greater number of papers ready for publication but this did not occur. In many cases, only preliminary results were presented by the WG members and discussed. It does not surprise, therefore, that the WG report for the Helsinki congress /Ziemann 1976/ was rather short. Nonetheless, the meeting was extremely valuable in that it gave almost every WG member a chance to personally discuss with other members their or his own procedure.

Few members of the WG had been able to attend the Stockholm symposium but most were able to participate in the Helsinki congress. The WG was allotted 75 minutes of one session. These were divided into 5-minute segments and given to the WG members present in Helsinki or to representatives of those not present, for a short review of their facility and/or procedure. Several WG members submitted presented papers on camera calibration /Ellenbeck 1976, Fritz and Slama 1976, Hakkarainen1976a, Kupfer 1976/ or on MTF or OTF determinations /Gliatti 1976, Hakkarainen 1976b, Rosenbruch 1976b/. One session of the OTF/MTF WG featured an invited paper summarizing the results achieved by Gliatti, Hakkarainen, Martin and Rosenbruch /Rosenbruch 1976a/. Several WG members were able to participate in the 1978 Tokyo symposium and some presented papers but only one presented results derived from data gathered as part of the WG project /Kupfer 1978/. A longer WG report summarizing all the results available until then, was also given in a session set aside for the WG /Ziemann 1978c/.

6. PUBLICATION OF RESULTS

It had always been hoped that at least one paper describing facility, procedures and results attained for the two réseau cameras used in the project would be published by each participant, preferably together, to produce a kind of compendium on camera calibration. A first letter was sent to the editor of Photogrammetria on 1975-06-11 in this matter in anticipation of the deliv-

ery of complete papers during the Ottawa WG meeting. Inquiries were also made about the printing of additional copies to be shipped to Helsinki. It was not until 1976-10-19, however, that the first four papers were actually submitted to Photogrammetria for publication /Hakkarainen 1976b, Martin 1977, Rosenbruch 1976 a and b combined, Gliatti 1976/. The papers had been received several months earlier in Ottawa, where they were reviewed to make them use the same designation for the cameras and conform to Photogrammetria's Note to Contributors, and returned to the authors on 1976-06-18 for another review. A request from Photogrammetria to write a guest editorial introducing the first four WG papers was received on 1977-05-11; the editorial /Ziemann 1977/ was mailed to Photogrammetria on 1977-05-27. Since the WG could not secure financial support for the publication of the papers, they appeared in two consecutive issues. One further paper was submitted immediately after the Helsinki congress in response to Photogrammetria's solicitation of publications during the congress; its publication was deferred with a letter dated 1977-07-11 to bring it into the intended sequence of publication of the WG papers. This letter served also as cover letter for the submission of two papers presenting results of lens distortion determinations with goniometers /Ziemann 1978a, Hakkarainen 1976a/. The first two papers presenting results from photographic laboratory camera calibrations /Carman and Brown 1978, Ziemann 1978b/ were mailed to Photogrammetria on 1977-08-23. These papers had all undergone the same editing steps as those submitted earlier, prior to their formal submission.

A rather unexpected surprise arrived on 1977-09-06 in the form of a letter from Photogrammetria's editorial office stating that the goniometer articles "contain(ed) insufficient new elements to be suitable for publication", an objection later withdrawn. Several letters followed regarding the inclusion of so many papers on camera calibration into Photogrammetria but arrangements suitable to both sides were eventually reached.

Two additional papers were submitted on 1977-11-15 /Tayman 1978, Fritz and Slama 1976/. No other papers have been submitted to Photogrammetria since that time, partly because the next paper to follow has been under review by the very busy author for almost four years now. This situation more than anything else underlines the fact that all contributions to the WG project were

- voluntary
- not specially funded
- carried out besides the normal work load, sometimes even outside regular working hours
- shelved for certain periods of time when normal work pressure so dictated

It is expected that the submission of manuscripts to Photogrammetria - who have been, with the one noted exception, a very cooperative publisher - will resume within 10 to 12 months in the order originally intended.

A final technical report, possibly appended by statements of several of the WG members, may be ready for publication at about the same time.

The bibliography attached to this report indicates further that other publications have been prepared based on material gathered

by the WG, and published elsewhere. This will probably continue to happen for some time to come.

7. PARTICIPATING AGENCIES AND THE FINANCING OF THE PROJECT

The following agencies participated in the project; WG members and/or (additional) contact persons are listed in brackets:

From Finland
- Institute of Photogrammetry, Helsinki University of Technology, Otaniemi (Prof. Dr. J. Hakkarainen - now with the Finnish Geodetic Institute in Helsinki, Prof. Dr. R. S. Halonen)
- Laboratory of Land Use, Technical Research Center of Finland, Otaniemi (Assistent Prof. H. Salmenperä - now with Tampere University of Technology in Tampere)

From the Federal Republic of Germany
- Institute of Photogrammetry, Bonn University, Bonn (Prof. Dr. G. Kupfer, H.-K. Ellenbeck - now with the State Survey Office of Northrhine Westfalia in Bonn)
- Optics Section, Physical Technical Federal Institute,Braunschweig (Prof. Dr. K.-J. Rosenbruch)
- Division of Geodesy and Photogrammetry, Carl Zeiss Oberkochen (Prof. Dr. H.-K. Meier, Dr. W. Lorch)

From Switzerland
- Division of Photogrammetry, Wild Heerbrugg Ltd., Heerbrugg (G. E. Bormann)

From the United States of America
- Department of Geodetic Science, The Ohio State University, Columbus (Ohio) (Prof. Dr. D. C. Merchant, Dr. W. Jiwalai)
- Photogrammetric Research Branch, National Ocean Survey, NOAA, Rockville (Maryland) (C. C. Slama, L. W. Fritz)
- Research Branch, U. S. Geological Survey, Reston (Virginia) (W. P. Tayman)
- Geodetic Services Inc., Indialantic (Florida) - formerly Division of Photogrammetric / Geodetic Services of DBA Systems Inc. - (J. A. Strahle)
- Optical Systems Division, Itek Corporation, Palo Alto (California) (J. A. Voggenthaler - now with .....)
- Optical Systems Division, Itek Corporation, Lexington (Massachusetts) (R. H. Howell)
- Air Force Avionics Laboratory, Wright Patterson Air Force Base (Ohio) (E. L. Gliatti, W. C. Martin)

From Canada
- Optics Section, National Research Council, Ottawa (Ontario) (P. D. Carman, Dr. H. Brown, Dr. I. P. Powell)
- Photogrammetric Research Section, National Research Council, Ottawa (Ontario) (Dr. H. Ziemann, Dr. A. Bujakiewicz - now with the Institute of Photogrammetry and Cartography, Warsaw University of Technology in Warsaw, Poland)

The project was carried out without a special budget. All contributions were not only voluntarily but were also financed by the participating agencies, who also assumed some of the transportation costs and, at times, unforeseen costs such as customs duty.

Financial Contributions to the project were also received from other sources:
- the Canadian Department of National Defence transported the

cameras from Canada to Germany and back, and aerial films during a mail strike in Canada, free of charge
- the Swedish Society of Photogrammetry, being responsible for Commission I at the time, covered transportation costs for the two cameras from Bonn to Helsinki and from Helsinki to Braunschweig
- the administration of the Division of Physics of the National Research Council in Ottawa provided a grant for the organization of the WG meeting helt in Ottawa on 1975-10-22/24
- the United States National Science Foundation provided a grant to D. C. Merchant to cover part of the salary of a graduate student, and the expenses for attending the Helsinki congress
- the German Science Foundation provided grants to Prof. Dr. Kupfer for his investigations, for attending the Tokyo symposium and for paying H. Ziemann's living expenses during his stay in Bonn

This list is incomplete but covers the larger contributions.

It is difficult to give cost figures for the project, because it was financed primarily out of operating budgets of the participating agencies. It is quite certain, however, that the overall expenses exceed $ 100 000.

8. CONCLUSION

This paper reviews the organization and execution of a project designed to
- demonstrate different procedures for the determination of interior orientation parameters including radially symmetrical and decentering distortions
- show problems related to the determination of two-dimensional (x,y) values for the overall lens distortion
- provide a comparison between the results of the different procedures
- provide data about the stability of the two lens cones used
- enable the determination of correlations between image quality and photogrammetric accuracy (as function of the location of image points within the image format)

Most of these objectives will only be realized as a result of an analysis of all available data through the same software which will enable a meaningful comparison not only of the effectiveness of the different sets of interior orientation data but also of the parameters with each other. The latter objective requires the use of the same coordinate system throughout and of similar image point locations for all the different procedures, two other reasons for reprocessing all data using the same software. Although this report was intended to be the final WG report, it must still be followed by a final technical report which will be submitted to the next Commission I symposium or the next congress.

The only WG related effort that is quantifiable is the correspondence which accumulated in a special WG file. The pieces were counted, divided between circular letters sent to all WG members (first number) and individual entries (letters, cables, telex messages):

1973	-	67
1974	-	160
1975	3	131

1976	1	126
1977	2	96
1978	-	96
1979	3	49
1980 (until 1980-02-20)	1	11

These numbers demonstrate that the WG has been rather active, in particular during the first four years while the various phases of data acquisition were carried out. The correspondence slowed down at about the time when preparations for the adjustment of the Sudbury test area triangulation and levelling were started in earnest. The correspondence of 1977 and 1978 includes a greater number of pieces directly related to the preparation of the Tokyo symposium, the correspondence in recent months letters related to the preparations for the Hamburg congress.

This report was mailed for review to all WG members involved with the project. Only few responded. The records on hand and the received replies were not sufficient to reestablish shipping dates and routes within the U.S.A., or to eliminate several other inaccuracies contained in this report.

All work carried out within the WG project has been contributed voluntarily, with very little special financing, with a low priority besides regular work and, to a certain extent, outside regular office hours. The realization of the project would not have been possible without the generous support of all agencies listed in section 7, without the personal support of all persons listed in section 7 and/or the bibliography, and without the effort of the technical support staff at the various agencies: the names Cecile DeChantigny, John Plummer, Allan Richens, Wilhelm Schröter and Allan Way Nee of five who contributed significantly, may stand for all of them.

It has been a priviledge to organize and chair this group and to benefit from the generous collaboration of many of the WG members.

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