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COMPILED BY

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Summary

The period under review marks an enormous increase of interest, activity and development in most phases of photogrammetry in Canada.

During the last four years, more than one million line kilometers of photography were flown for Federal and Provincial agencies. In addition, SAR imagery, colour and colour infrared photography, MSS, LIDAR Bathymeter, LASER Profilometer, microwave scatterometer, MEIS Linear array scanner, and Landsat data have been used regularly for various purposes. Extensive research has taken place on camera calibration, system calibration, lens distortion and film deformation, and the use of new type of film (KC-film) for photogrammetric purposes.

In the field of instrumentation, there has been a steady increase in the involvement of Canadian institutions and industry in developing and using instruments and systems for automation and digital mapping. An increasing number of analytical plotters is now in use for research and production purposes.

In the mathematical analysis of data, computer programs for block adjustment with the state-of-the-art algorithms have been developed and are now in use in various organizations in Canada and elsewhere. Many significant developments have taken place in gross and systematic-error detection and elimination, on-line triangulation, and block adjustment with various types of auxiliary control. Also, an increasing attention has been given to the application of photogrammetric techniques to digital images.

The scope of applications of photogrammetry for non-topographic purposes has widen considerably in Canada. As an example of the new fields of applications; six 16-mm movie cameras, installed in the payload bay of the Space Shuttle "Columbia", were used to monitor the performance of the remote manipulator system during several flight missions. Other interesting applications include; the automatic detection and diagnosis of scoliosis using moiré imagery, robotic vision systems, and many other engineering and medical applications.

The education and research activity has steadily grown, particularly in remote sensing. There are four universities (New Brunswick, Laval, Toronto, and Calgary) offering a full surveying program, that includes photogrammetry and remote sensing, both at the undergraduate and graduate level. Many other colleges offer some courses in photogrammetry and remote sensing throughout the country. Although the number of undergraduate students has stabilized over the last four years, the number of graduate students has increased by about 50% over the same period.

There has been a significant increase in remote sensing applications, mainly within the realm of aerial photography, with some increase in the use of satellite data and airborne and spaceborne thermal and radar data.

This report has been compiled from information received from a number of organizations and individuals. Thanks are due to all those who have contributed and to the national reporters who took the time to prepare the material for the following detailed activities of the seven commissions.

Commission I
Primary Data Acquisition

Reporter: E.A. Fleming, Department of Energy, Mines and Resources, Ottawa.

AERIAL PHOTOGRAPHY

Aerial photography is carried out by commercial companies to meet the needs of Federal and Provincial mapping, resource exploration and management and large-scale mapping and engineering projects. In addition to this commercial capacity, government-owned aircraft provide platforms for experimental work in sensor development. There are approximately 15 aerial survey companies operating in Canada using a variety of aircraft generally falling in the category of unpressurized light twins. Some single-engine aircraft are used, and for high altitude work, jet or prop-jet aircraft are used.

During the period 1980-1983 1,005,153 line kilometers of photography were flown for Federal and Provincial agencies, which can be broken down as follows:

Aerial Photography (1980-1983)

		Federal	Provincial
1.	Photo-scale	(248,000 l.km)	(757,153 l.km)
	1:50 000 and smaller	69%	16%
	1:6 000 to 1:50 000	28%	82%
	larger than 1:6 000	3%	2%
2.	Cameras (Wild, Zeiss)	(118,000 exposures)	(536,329 exposures)
	wide-angle	81%	81%
	super-wide-angle	19%	1%
	normal angle *	-	18%
3.	Films (Kodak)		
	Double-X (2405)	85%	74%
	Plus-X (2402)	-	1%
	IR (2424)	-	6%
	Colour (2445)	9%	14%
	Colour IR (2443)	4%	5%
	Pan-X (2412) **	2%	-

Navigation: Visual navigation methods are used for most aerial photography done over continental Canada, however some companies have added closed circuit TV, Doppler, GNS, Omega VLF, and Del Norte microwave positioning to

Notes

* The normal angle cameras are used primarily for forestry surveys in mountainous areas. A small amount of long-focus (60 cm) photography is done for forestry sampling.

** Operational testing in 1983.

cope with the more difficult navigation problems encoutered off-shore, overseas, or in very large scale forestry work.

Processing: Continueous processing machines are used almost exclusively. Re-wind processing capability is maintained for overseas contracts and some colour processing.

Supplementary airborne data: One company specializing in forest inventory uses an FPR1 Forest Penetrating radar and low level APR, HMI tip and tilt recording device and a Del Norte 540 microwave positioning system for line spacings of 60m or less.

SIDE LOOKING RADAR (SAR) IMAGERY

Imagery obtained from SAR systems provides ice reconnaissance data for shipping, exploration and drilling operations in arctic waters. An APS 94D Motorola SAR is used in a Grumman 81 aircraft equipped with an LTN-72 intertial navigator, Omega, Doppler and a radar altimeter. Negatives on 9 1/2 film are produced on board the aircraft and dropped by parachute to the ice observation stations on a daily basis. There they are interpreted and ice maps are sent by faximile to drill rigs and ships operating in the areas monitored. Two Electra aircraft of the Atmospheric Environment Service equipped with similar SAR, monitor areas not covered by commercial operators.

SAR imagery is also acquired for forestry and geological purposes both in Canada and abroad. Radar mosaics have proved useful for this work as well as for base maps in countries having a high incidence of cloud cover.

CANADA CENTRE FOR REMOTE SENSING

Aerial photography is flown in support of the development of new sensors and remote sensing techniques. Approximately 50,000 line km were flown during the 4-year reporting period, with maximum use being made of Wild RC-10 wide-angle cameras. The principal films used were colour and colour infrared. In addition work has proceeded on the applications and development of SAR, MSS, LIDAR Bathymeter, LASER Profilometer, microwave scatterometer and the MEIS linear array scanner.

The Convair CV580 aircraft has been used to demonstrate SAR capabilities in L-, C-, and X- bands. The demonstrations both in Canada and abroad are in support of the development of space systems.

Navigation equipment used on these airborne operations includes Litton LTN51 Inertial System, Global VLF System, and CCTV for track following and quick look imagery.

SPACE IMAGERY

Canada has operated receiving stations for Landsat data throughout the period 1980-1983. Two stations were operated until October 1982 when the imposition of station fees by NOAA forced the closure of the Shoe Cove Station in Newfoundland. Coverage of the east coast is now obtained from U.S. receiving stations. The Prince Albert station in Saskatchewan, which receives data for the remainder of the country was up-graded to X-band reception of the TM Mapper in July 1982. Due to uncertainties in the data continuity of the Landsat program and the yet-to-be-established reception

arrangements for SPOT, MOS and ERS-1 no move is being made to re-establish the station in a more central geographic location.

Imagery received (1980-1983)

Landsat MSS	112,196 scenes
Landsat RBV	38,140 scenes
Landsat TM	2,340 scenes

The Canada Centre for Remote Sensing is responsible for receiving, archiving and distributing this imagery. For the fiscal year 1981-82 the following statistics were available:

Total sales of imagery:		$400,710 Can
Users:	Geology, oil	55%
	Forestry	15%
	Environment	15%
	Agriculture	10%
	Other	5%

COMMISSION I ACTIVITIES

Working Group I/2 on "Camera Calibration and Effects of the Environment" has been active under the joint chairmanship of Dr. Hartmut Ziemann (Canada) and Mrs. Clarice Norton (U.S.A.). The results of this work was reported at the Commission I meeting in Canberra, Australia 1982 under the following titles:

"Report on Activities of Working Group I/2" H. Ziemann & C. Norton
"Photogrammetric Camera Calibration" H. Ziemann, W. Tayman
"System Calibration vs Self Calibration" H. Ziemann, S.F. El-Hakim
"On the Definition of Lens Distortion reference data with odd-power polynomials" H. Ziemann, S.F. El-Hakim
"A Photogrammetric Test Image" H. Ziemann
"The Mega-Printer - An Electronic Copier for photogrammetric processes" H. Ziemann, P. Loosberg

(Published in the proceedings of the Symposium)

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COMMISSION II

Instrumentation for Data Reduction

REPORTER: Dr. M. Mosaad Allam, Surveys and Mapping Branch, Energy, Mines and Resources Canada

In Canada, the period between 1980 and 1984 has been characterized by an increased involvement of the Canadian photogrammetric institutions and mapping industry in digital mapping. Federal and provincial agencies of various levels and private mapping firms are involved in the development of digital photogrammetric map compilation systems, by the interfacing of analog and analytical instruments to digital information systems.

At the federal level, the Topographical Syrvey Division, Surveys and Mapping Branch, Department of Energy, Mines and Resources, is actively engaged in a program for digital photogrammetric mapping and the Mapping and Charting Establishment, Department of National Defense facilities by the acquisition of three Marconi Anaplot II analytical plotters. At the provincial level, several provincial agencies and municipalities have installed new digital mapping systems (e.g. Alberta, British Columbia, Quebec, Ontario and the Maritime Provinces). Responding to users demand for digital topographic data, the Canadian mapping industry is also involved in digital mapping (e.g. Kenting Sciences, Terra Surveys, Northway - Gestalt, etc.).

The Photogrammetric Research Secion, National Research Council of Canada is actively engaged in a program for the development of new concepts in the design of instruments and systems for the automation of photogrammetric processes. Instruments developed at the Section are continuously upgraded. The development of the prototype electronic image-transfer assembly incorporated into the ANAPLOT system, and the development of the associated remote control station with a separate set of primary operator's controls, have been continued at the Section. The NRC Stereocompiler has been adapted to provide the means for on-line digitizing to allow the experimenting needed for the development of an on-line land information data acquisition system. This work was performed as a part of the Pilot Project Cadastre Latin America, which aims to establish a model for multi-purpose cadastral system based on the use of techniques developed by NRC.

Development of instruments and hardware for photogrammetric digital image processing is underway at NRC. A complete experimental stand-alone real-time low-cost system for image capture, digitization, processing and display has been built and is undergoing tests. It is capable of image transformation in applications involving dynamic processes such as robotics and medical monitoring and diagnostics. A high-speed digital correlator/convolver is

under development. Digitized-enhanced images are compared or otherwise analyzed by correlation and/or convolution involving image sliding in digital memory.

A novel instrumentation concept that addresses the problem of reliable real-time position determination on the photo has been developed at NRC. In this comparator technique, the photo is placed with its emulsion in contact with a 2-D plane grating and the viewing and measurement points are arranged to be physically coincident.

Manufacturing of photogrammetric instruments in Canada continued with the development of the new Series IV GESTALT Photo Mapper. Eleven GPM systems are presently operating in Canada, Algeria, Colombia, Japan, Spain and U.S.A. A number of Anaplot II analytical plotters have been manufactured by Canadian Marconi Company and are in use at some government institutions.

The Canada Centre for Remote Sensing (CCRS), Dept. of Energy Mines and Resources, is involved in several programs for the development of systems for the processing and reduction of remotely sensed data. In cooperation with private industry, CCRS has developed an airborne remote sensing and analysis system for water parameters, and a real-time data correlator for the airborne Laser flurosensor. Projects dealing with synthetic aperture radar imagery are being conducted by CCRS and the Radarsat Project Office. Another development by CCRS is the digital image correction system (DICS).

Canadian private industry led by MacDonald, Dettwiler and Associates (MDA), is a leading supplier of digital systems in the fields of remote sensing. MDA is involved in development of the Earth Resource Satellite, Meteorolofical Satellite Data Systems, and SAR processing. DIPIX Systems Limited manufactures the ARIES digital image analysis system for the processing of remote sensing data. The ARIES system is currently in several countries in Europe, Asia, North and South America, and is capable of processing digital imagery from Landsat, NIMBUS, TRIOS, SEASAT-A, NOAA, SEASAT and airborne multispectral scanners. Instrument development by Canadian firms include the manufacturing of simple systems, such as the PROCOM, developed by Gregory Geoscience Limited which is an optical projection compositor for superimposing and registering landsat imagery to maps for the derivation of thematic information.

Canadian Universities are also active in the development of instrumentation and techniques. At the University of New Brunswick, a prototype of a simple analytical plotter was developed by S. Masry at the Department of Surveying Engineering.

In recogition of the role of Canadian mapping institutions, research organizations and private industry, Canada hosted the ISPRS Commission II for the period 1980-84 with Z. Jaksic as a president of the Commission.

The ISPRS Commission II Symposium on advances in instrumentation for the processing and analysis of photogrammetric and remotely sensed data, was held in Ottawa from August 30 till September 3, 1982.

In conclusion, activities in the field of instrumentation for the reduction of data is continuing vigorously in all the photogrammetric and remote sensing institutions in Canada and the future looks quire encouraging.

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COMMISSION III

Mathematical Analysis of Data

Reporter: S.F. El-Hakim, NRC, Ottawa, Ontario

During the last four years, Canadian research institutions, universities, and some mapping industry have been very active in the various fields of commission III. Computer programs with the state of art algorithms have been developed and are in use in various Canadian organizations and all over the world. Research has been particularly extensive in systematic and gross error detection, on-line triangulation and recently, digital image processing. The last topic is now emerging as a major concern of commission III activities in Canada.

Methods of Block Adjustment:

At the University of New Brunswick (UNB), a research on applying modern

aerotriangulation methods with analogue plotters has been completed. The potentials of these instruments, which are still in use in the mapping industry, as measuring tools for bundle adjustment and independent models with self calibration have been investigated and some measuring techniques have been developed and tested.

A program for independent models block adjustment has been completed at the National Research Council (NRC) by G.H. Schut [Schut 1980], and is now in use in many organizations in Canada and elsewhere. The program may operate on any type of computer, including mini-computers, and has some features as the use of additional parameters for correction of model deformation and the possibility of using auxiliary vertical control such as lake shoreline points.

Also at NRC, the program GEBAT (General Bundle Adjustment Triangulation) has been completed [El-Hakim and Faig, 1981, El-Hakim, 1982]. It is a combined photogrammetric and geodetic adjustment with features like a full self-calibration, the use of auxiliary data and gross error detection by "data snooping".

At Laval University, modified bundle adjustment methods have been developed to perform aerial triangulation with space photography [Ali and Braudenberger, 1982].

The concept of photo-variant self-calibration and its application in block adjustment with bundles has been investigated, first at UNB then at the Land Registration and Information Services (LRIS), PEI [Moniwa, 1981]. Although this approach requires a more laborious computational effort, it is a generalized self-calibration scheme applicable for any type of camera and photography. It assigns an individual set of compensation parameters to each photograph or group of photographs which makes it useful for unstable cameras or films or in cases where more than one camera and/or different types of film have been used.

Auxiliary Control for Block Adjustment:

At the University of Calgary, the block adjustment program SPACE-M has been extended to accommodate auxiliary airborne data corresponding to the position and/or attitude of the aerial camera at the time of film exposure [Blais and Chapman, 1983b]. Examples of such systems are statescope, laser profilometers, Inertial Navigation Systems (INS) and the Global Positioning System (GPS). SPACE-M has also been extended to make use of local networks of terrestrial control points with unknown translation, orientation and scale biases with respect to the geodetic reference datum. Data from modern surveying techniques, such as "total-station" surveying instruments or satellite receivers, which provide spatial locations in some Cartesian reference system or coordinates, can be used directly in the program [Blais and Chapman, 1983c].

The program GEBAT has been tested extensively at NRC for the use of terrestrial observations as replacement for some control points. The program was used in a control-densification project for the City of Sudbury and an accuracy of 2 cm in horizontal coordinates was achieved with minimum control and some perimeter distances [El-Hakim, 1982a].

At the University of New Brunswick, external navigation data, from INS, have been utilized with bundle adjustment.

Accuracy Aspects and Quality Control:

Extensive research on gross-error detection, mainly with the method of data snooping, has been carried out at NRC [El-Hakim, 1981b, 1982b]. A step-by-step strategy has been developed to detect errors of different types and sizes [El-Hakim and Ziemann, 1982]. Factors affecting the detection of these errors, such as block parameters, number and location of points, and additional constraints have been studied and, as a result, recommendations for planning photogrammetric projects have been drawn. A theoretical and practical analysis of the different criteria to express photogrammetric accuracy have also been carried out [El-Hakim, 1981a]. The most meaningful and reliable criterion of expressing photogrammetric accuracy have been recommended.

On-Line Photogrammetric Triangulation:

The on-line triangulation programs for the NRC Anaplot are primarily aimed at quality controlled data acquisition followed by an independent off-line block adjustment. The most recent refinements of the software result in a significant reduction of preparatory work, higher production efficiency and the improved control of gross errors [Kratky, 1981, 1982 and Kratky and El-Hakim, 1983]. By choosing tie and pass points during the measurement process, one avoids problems otherwise associated with their identifications and drastically reduces the time necessary for preparatory triangulation work. The tedious and time consuming selection of pass points in image overlaps, which may involve comparison of up to six adjacent photographs at a time, becomes unnecessary. Also redundant is the point transfer by marking of photographs in special devices and manual point numbering. The NRC on-line triangulation offers this alternative. It represents a fast and efficient procedure with an adequate checking power to produce accurate data practically free of gross errors and blunders. Thus, it greatly simplifies the ultimate off-line block adjustment of data.

Another recent research at NRC is the simulation of analytical plotters and interface functions by software using a suitable interactive terminal [Kratky, 1984]. This simulation is an important tool in developing software and in its testing without the presence of hardware components. It may also be useful in standardization of on-line analytical systems or the development of more universal system software.
Software packages for the Canadian Marconi Anaplot have been developed [Turner, 1982]. They include a basic application package, an aerial triangulation package, a map compilation and digitization package and a non-conventional imagery package. The aerial triangulation package uses a continuous strip method with quality controlled on-line data collection. Strips are assembled by an off-line program, and it is possible to reset any model from the triangulation data banks for subsequent compilation.

At the University of Calgary, theoretical aspects and algorithms for on-line triangulation have been investigated. Recursive least squares estimation using Givens transformations have been applied to on-line photogrammetry. The Givens transformations have a number of advantageous characteristics in terms of data storage requirements, numerical stability and computational efficiency [Blais, 1982].

Digital Terrain Information:

At Energy, Mines and Resources, problems associated with DEM's generated by means of fully automated photogrammetric instruments have been investigated

[Allam, 1982]. The main problem is with accuracy because the data are not homogeneous. Filtering of noise, smoothing of data and editing of elevations are the approaches developed to solve this problem.

At Laval University, a method for forest mapping, where the terrain is inaccessible, has been developed. In this method, DEM is extensively used to provide the necessary height control [Leupin and Ettarid, 1982]. The method allows the production of forest maps at a substantially lower cost without compromising on accuracy.

Digital Image Processing:

The application of photogrammetric techniques to digital images requires particular attention to the meaning and preservation of geometric integrity in the image. Current image-processing techniques and practices do not adequately address this issue. Research on the basic problems and techniques involved in working with digital image geometry is in progress at NRC. Aspects of pointing precision which are fundamental and specific to digital imagery are being studied [Havelock, 1984]. A small library of digitized stereo aerial photography suitable for limited photogrammetric analysis has been generated. Methodologies and techniques for the analysis of these data are being studied. Spectral analysis and array-algebra techniques continue to be studied to provide efficient alternatives in real-time processing of data generated by on-line photogrammetric systems and in photogrammetric image correlation [Kratky, 1981]. An effort is under way to reformulate and modify the essential functions of present on-line photogrammetric systems for their implementation in the environment of digital image processing.

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COMMISSION IV

Cartographic and Data Bank Applications for Photogrammetry and Remote Sensing

Reporter: Claude de Saint Riquier, Mapping Branch, M.E.R. Québec

In Canada, the period from 1980 to 1984 has seen the pursuit of the development of automated systems for photogrammetry and cartography. During the same period, different federal, provincial and municipal organisms have set up some automatic systems in surveys and mapping for the acquisition and processing of digital data as well as carrying decrease of production costs.

It should be noticed that, for the same period, the canadian industry for photogrammetric mapping, which is directly in connection with the economical development of this country, has not escaped from the world wide economical crisis, and has encountered an important recession for the production and revenue.

The topographical Survey Division, Surveys and Mapping Branch, EMR, continued to refine its interactive digtal compilation system which is being applied to the photogrammetric compilation of urban and semi-urban maps at the scale of 1:50 000 and to create the National Digital Topographic Data Base. The system, now in full production, makes use of two types of files:

- a Position File which contains edited data collected in digital form directly on photogrammetric instruments. In this file, topographic features are recorded in their true position without regard to cartographic symbolization. The Position File is the basis for the National Digital Topographic Data Base.

- a Cartographic File which is created by the cartographer from the Position File by displacing and deleting features, by selecting symbols and issuing appropriate commands for the automatic drafting of colour separation negatives.

The Division is also using its Gestalt-Photomapper to produce orthophotomaps at the scale of 1:50 000 and Digital Elevation Models (DEM). Contour plates for those maps are then automatically produced from those DEM's using software developed by the Division.

The Division is successfully using Landsat imagery to revise 1:250 000 maps by visual comparison of the imagery and the map to be revised. The method, developed by a private company, Gregory Geoscience Ltd. of Ottawa, has proved to be fast and cost effective. The same approach is used to detect changes on 1:50 000 maps and thus determine where aerial photography is needed for revision purposes. It has been shown also that by utilizing Landsat digital image analysis techniques, large concentrations of small lakes can be mapped at scales of 1:250 000 to 1:1 000 000 in a more descriptive manner than the current cartographic practice for maps of those scales. Experiments are also being carried out to detect changes using the same digital image analysis technique.

Under the auspices of the Canada Council on Surveys and Mapping in cooperation with a wide spectrum of producers and users of digital terrain information, a set of National Standards for the Exchange of Digital Topographic Data was developed. These standards cover the classification (taxonomy) of topographic features, standards for quality evaluation and EDP standards.

The different provinces, for their part, have started off a mass production with the numerical mapping at large and medium scales. These data are mainly used for producing the base mapping at a scale of 1:20 000 and for creating a mapping data base for a multi purpose exploitation.

Some noteworthy accomplishments have been carried out and an appraisal has been developed with the municipal mapping at large scales. The numerical data allow a geographical basis for urban information systems needed by municipal administrations and also large public utility companies.

The canadian mapping industry, which is formed of about twenty five firms, was brought to participate for the national mapping production as well as maintaining an important commercial presence on the international market. The field of occupations and at 1:20 000 for the national and provincial mapping up to large scales for municipal plans at 1:500.

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COMMISSION V

Other Applications of Photogrammetry and Remote Sensing

Reporter: Dr. Wolfgang Faig, Department of Surveying Engineering, University of New Brunswick

Although the number of organizations involved in non-topographic applictions of photogrammetry in Canada remained relatively small, the scope of applications has widened considerably. This may be attributed to a rather healthy mix of not only universities and photogrammetric research organizations but also of private companies, government agencies and other interested groups which frequently are utilizing photogrammetry as an important and unique mensuration approach.

The report lists the main activities in Canada in the area of interest of Commission V for the period 1980-1984. Various developments and applications are briefly described, with proper reference to relevant publications, which are listed at the end of this report. By concentrating on new developments which found their way into the published literature or at least were considered worthy to be passed along to this reporter, certain routine applications of interest to this Commission may not appear as prominently as they perhaps should. One example is the field of architecture, which was barely mentioned in any submission. However, close-range photogrammetry in being routinely used within the Restoration Services Division of the Department of Indian and Northern Affairs and also - less frequently - by other organizations.

Instrumentation

With the continued use of metric cameras and the successful utilization of non metric cameras, especially in close-range applicaitons, cameras of any type appear now to be classified as routine instruments. Thus the emphasis has shifted towards different aspects of data collection.

At Laval University, research concerning Electron Micrography is in progress. This involves both Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM). The study aimed at a total understanding of the electron micrographic systems towards their applications in 3-D precision measurements. Both perspective and parallel projection geometries for the imaging system are being tried. Self-calibration techniques with fundamental collinearity condition equations are used for deriving mathematical models to describe various inherent distortion and orientation parameters. This multi-disciplinary study involves scientific subject areas of metallurgy and anatomy [18] and [19].

At the National Research Council, a program is underway to develop a real-time, low cost, digital image capability for processing images of a moving oject. The purpose is to obtain automatic decisions about the object and to control its position in 3-D space. An experimental system is currently undergoing tests, and refinements consist of photoelectronic image capture and digitization, a digital spatial filter correlator/convolver, and displays. The focus is upon image enhancement and towards solutions in real-time, in-situ, filmless photogrammetry of dynamic processes [21].

Gary Robertson, Photogrammetric Consultant Inc. developed a photogrammetric measuring system based on an image scanner capable of target recognition. The work stemmed from the development and implementation of a photogrammetric software system to a Perkin Elmer PDS micro densitometer, which has the capability of target recognition and centroid measurement. The system is based on a micro processor which is directly interfaced to a digital image processor system.

The major breakthrough with this Robotic vision system is the elimination of operator errors, since all targets are read automatically without any operator. The system is primarily designed for industrial close range photogrammetry, but could also be used in aerial triangulation.

Within the last decade, there has been a considerable increases in the use of small non-metric camera and other sensing systems from remotely controlled ultra-light aircrafts. At British Columbia Research, the feasibility, advantages and limitations of using remotely piloted aircraft to acquire aerial photography for environmental applications are being studied. A three-metre span fixed wing prototype aircraft, carrying a 35mm camera system has been successfully applied for a variety of tasks in forestry, pollution detection, site and shoreline mapping as well as for wildlife inventory [24].

Mathematical Modelling

Work in this area is concentrated at the Universities and Research Centres. The Program System GEBAT, developed at the University of New Brunswick [5] has been modified at the National Research Council to meet the specific needs arising in close-range applications where a non-metric camera is employed. The GEBAT-V program uses spatial distances and height differences as control, while self calibration is arranged in a photo-variant mode, i.e. each photo has its own calibration parameters (principal distance, principal point coordinates, and 8 paprameters of a harmonic function for systematic error compensation). In addition, gross error detection is applied using the data snooping approach. Finally, the variance-covariance matrix and error ellipsoid for each adjusted object point is computed [9].

At the University of Calgary, research endeavours into specialized applications of photogrammetry comprise mainly work in the area of analytical non-topographic photogrammetry.

As part of an ongoing investigation into close-range photogrammetric systems, features of variance analysis have been examined, especially in relation to minimally constrained photogrammetric adjustments [10]. In addition, through consideration of the different orders of the design problem, aspects of network optimization are being studied [16].

With regard to non-metric camera applications, research has principally involved an investigation into film deformation effects on the analytical restitution of non-metric images [12]. This work forms part of a wider study of accuracy enhancement techniques, through the use of specialized self-calibration approaches, for photogrammetric measurement with amateur cameras [13].

Engineering Applications

A number of projects in this area are presently being carried out at the National Research Council. For instance, six 16mm movie cameras, installed in the payload bay of the Space Shuttle "Columbia", were used to monitor the

performance of the remote manipulator system during several flight missions. Special calibration procedures were carried out in the laboratory and on board of the Space Shuttle to determine the exterior and interior orientation parameters of the cameras. The results of the photogrammetric analysis are used to evaluate the performance of the arm during the space mission [26] [27].

The GEBAT-V program was applied to determine the geometrical properties of microwave antennae. These large antennae are required to be manufactured with a high accuracy in order to receive clearly certain wave lengths. The accuracy achieved for this application was better than 0.1mm.

Similar work is being done by Gary Robertson who has installed a photogrammetric software and training program with a major manufacturer of fighter aircraft, and has been involved in photogrammetric measurement of radar dishes. Furthermore, the company has been very active in R&D related to the image scanner, ultrasonics and specialized computer software. The main areas of application are mining, geotechnical- and structural engineering, architectural applications and the monitoring of building deformations. The company is also involved in training programs for industry in areas of close range applications and has set up several units among industrial users.

At the University of New Brunswick, a tunnel profiling system was modified for use in the volume determination of a penstock at a power dam in New Brunswick [6].

Applications of Photogrammetry in Mining and Deformation Studies

The Department of Surveying Engineering at the University of New Brunswick has been deeply involved in subsidence studies under extreme climatic and topographic conditions. Photogrammetry forms an integral part of these investigations and has yielded excellent results in spite of rather adverse conditions [1] [2] [4] [7] [8].

The use of photogrammetry as a high-precision deformation measurement technique is being investigated via two practical studies at the Division of Surveying Engineering, University of Calgary. The first involves the monitoring of a potentially hazardous landslide area using low level aerial photography, coupled with free-network adjustment, sensitivity analysis and network congruency testing [14] [15] [17]. A second deformation monitoring project, which is currently underway, involves the structural analysis of thermally induced deformations in exposed concrete panels on a large autitorium in Calgary. The movements due to thermal loading are being measured, at the half-millimetre level, photogrammetrically.

Several private companies are involved in slope stability measurements [23], volume determinations [25] and similar work.

Bio-Medical Applications

Research into automation of moire imagery is being carried out at the National Research Council. In order to enter the field of digital processing, a commercial work-station was acquired and installed in March, 1982 (ARIES-II from DIPIX Systems Ltd). An initial set of 30 moire topograms was digitized for the tests. Analysis software is presently in the early stages of development. The main application is in the field of automatic detection and diagnosis of scoliosis in school screening programs.

Since the summer of 1981 the division of Survey Science at the Erindale Campus of the University of Toronto has been participating with the McMaster University Medical Centre in an investigation of the effectiveness of applying close-range photogrammetry to the measurement of topical ulcers. This investigation is preliminary to an anticipated randomized clinical trial that would compare a newly developed clear plastic dressing with standard wound dressing in treatment of the ulcers.

The photogrammetric procedure is based on the method developed in Sweden and reported on by G. Eriksson, A.E. Eklund, K. Torlegard and E. Dauphin in the paper "Evaluation of leg ulcer treatment with stereo photogrammetry" appearing in the British Journal of Dermatology (1979) 101, 123.

Photographs were taken by a pair of 35mm Medical Nikkor cameras mounted with a strobe lamp on a bar at a base distance of approximately 340mm, with axes converging at a point approximately 1000mm in front of the lenses. The bar is designed such that it can be comfortably held by a nurse or medical technician and used quickly within a clinical environment.

A preliminary test of the procedure was made using models of ulcers cut from tulips. Tests on actual ulcer patients followed. Some forty pairs of stereophotographs on 12 patients were processed.

Although there was, at times, some difficulty in interpreting the edges of the ulcers, the results of the tests are, in general, quite encouraging. It is hoped that the procedure can be applied in the near future to a full randomized clinical test.

At the Laval University, research in biomedical applications continues in the following areas:

X-ray photogrammetry: This is with regard to developing a new surgical intervention technique aimed at treating epilepsy patients. It requires the introduction of probes into the skull of the patient such as would cause no internal damage. Convergent photogrammetry, self-calibration and collinearity condition with modifications adaptable to radiography are being investigated. The concept of "floating line" is pursued. This inter-disciplinary research involves research with mechanical engineers and neuro-surgeons [3].

Close-range photogrammetry in the area of biomechanics: This concerns obtaining multi-dimensional data (X, Y, Z, time and more) on human knee-bones. This is aimed at developing viable techniques for repairing movable human limbs accidentally damaged during work, games, etc. It involves combining 5 and more stereo-models for obtaining digitally expressed surfaces of bones. The data are afterwards subjected to relevant and deliberate changes. This is also a multidisciplinary research involving mechanical engieering and medicine. Parametric description of the object surface to serve mechanical engineering developments is one of numerous objectives [20].

Anthropometric studies of human hands: This close-range photogrammetric study is aimed at obtaining statistical data on numerous hands of laborers in forest related outdoor work. The required data being digital and three-dimensional at specific points with necessary precision of 0.5mm or less, use of stereometric cameras such that 4 hands placed in the same stereo-model seems to work in a cost-effective manner. Medical rehabilitation related statistical studies are involved here. Only feasibility studies have been completed. This is expected to develop into an extensive industry related program.

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COMMISSION VI

Economic, Professional and Educational Aspects of Photogrammetry and Remote Sensing

Reporter: Dr. M. Leupin
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Introduction

Since the last congress in Hamburg 1980 education and research activity in Canada has steadily grown, particularly so in remote sensing. This is mainly due to the increasingly important role played by this discipline in natural resources assessment and management. More and more educational institutions add now some courses on remote sensing to their curriculum.

Until recently, research in photogrammetry and remote sensing was mainly done at Universities and Governmental agencies. Another member has joined the group, as more and more research contracts are being given out to private enterprise which clearly indictes the growing importance of photogrammetry and remote sensing in Canada.

Education

Four Universities (New Brunswick, Laval, Toronto and Calgary) offer a full surveying program both at the undergraduate and graduate level. Although there is still no separate undergraduate program in photogrammetry or remote sensing, these disciplines are well covered within the surveying program. But the days of separate programs, particularly in remote sensing, may be not too far away in Canada.

Student numbers in surveying have somewhat stabilized due to the uncertain economic situation, although the annual output remains at a relatively high level. The more significant growth has taken place on the graduate level, where the number of M.Sc. and Ph.D. students in photogrammetry and Remote Sensing has increased by approx. 50% in the last four years.

Likewise, student enrollment at the college level is reported to be constant. A recent survey made by the Canadian Institute of Surveyors has revealed a surprisingly large number of Colleges offering courses in photogrammetry and remote sensing throughout the country.

Research

As mentioned before, research is done at three levels in Canada:

- government
- universities
- private enterprise

Judging from the publications and the participation at congresses, symposia, etc., research activity in photogrammetry and remote sensing is well alive in Canada. On the governmental level, the three most important research groups in photogrammetry and remote sensing are the Photogrammetric Research Section at the National Research Council (NRC), the Topographic Research Section within the Department of Energy, Mines and Resources and the Canadian Centre of Remote Sensing, all in Ottawa. At the provincial level, several provinces carry on specific research activities corresponding to their specific needs.

University research funds now total about 500'000 $ annually, a substantial increase in the last four years. The same can be siad for private enterprise, although exact numbers are not available.

Commission activities

Canada is actively involved in Commission VI, particularly in three working groups:

- W.G. VI-I: Inventory of Manpower and of Education + Research Facilities. Chairman: Dr. A.J. Brandenberger, Laval University, Québec.

- W.G. VI-2: History of Photogrammetry and Remote Sensing. Chairman: Dr. T.J. Blachut, Ottawa

- W.G. VI-8: Stimulatlion of Education in Photogrammetry and Remote Sensing. Chairman: Dr. S.K. Ghosh, Laval university, Québec

Please refer to the respective reports on the activities of these working groups.

Conclusions

Despite a stagnant economy during most of the last four years, research and education activity in Canada has been constantly growing. As a result, the profession is gaining in strength and will be well prepared to tackle the future, whatever it may hold.

COMMISSION VII

Interpretation of Photographic and Remote Sensing Data

Reporter: Dr. Simsek Pala, Ontario Remote Sensing, Toronto, Ontario

Since 1980, there has been a gradual, widespread increase in remote sensing application in Canada, still predominantly within the realm of aerial photography, but with increased use of satellite data and airborne and spaceborne thermal and radar data. Among these more recent forms of remote sensing data, there are as yet few applications actually established in operation. Those few methodologies which are so established, however, are significant in both their practical benefit and their promise of wider application in the future.

In the Forest Inventory Branch of the Government of British Columbia, forest depletion mapping from LANDSAT imagery fulfils a legislative requirement for yearly forest area inventory. In Ontario, a combination of digital LANDSAT analysis and automated map production forms the basis for a province-wide peat resource inventory. This same technique has been tested with considerable success in forest and land use mapping and agricultural land use inventory. The Topographic Survey of Canada now employs LANDSAT data to determine with topographic maps need to be revised, and to determine the precision location and size of waterbodies.

A number of important developments have taken place in the Canada Centre for Remote Sensing (CCRS), Canada's national remote sensing organization. One of the two satellite receiving stations in Canada, the station located in Newfoundland, was closed. The ramaining station has been updated to receive

LANDSAT 4 TM data, and is being outfitted to process this data. CCRS has also embarked on the development of a digital image analysis system adapted to the level of detail and data volume of TM. CCRS has developed technology and applications of microwave sensing, especially for ice classification and imaging. LIDAR bathymetry was used in coastal hydrography. Airborne MSS data was used to simulate the improved resolution to be offered by the LANDSAT 4 and SPOT satellites.

CCRS has taken an important step in commencing planning of RADARSAT, a Canadian satellite designed principally for ice and coastal monitoring. Scheduled for launch in 1990, the satellite will carry a multi-beam radar and two other sensors which are yet to be determined. A geographic and disciplinary cross-section of Canadian remote sensing practitioners is represented on the RADARSAT planning committees. The land-resource capabilities of satellite radar will be investigated by a number of Canadian researchers who will receive data from NASA's second Shuttle Imaging Radar mission.

The level of activity remained fairly constant within the discipline-oriented national working groups reporting to the Canadian Advisory Committee on Remote Sensing (CACRS), and advisory body to CCRS. The Interprovincial/territorial Advisory Sub-Committee to CACRS continued to actively promote the interests of the individual regions of the country vis-à-vis the federal remote sensing program.

On the provincial level, Canada now has central remote sensing organizations in five provinces (Alberta, Manitoba, Ontario, Québec and Nova Scotia). All five centres possess digital satellite data analysis systems. A Maritime Remote Sensing Committee has been formed to coordinate the dealings of Canada's four easternmost provinces with the federal remote sensing program.

Numerous universities and colleges across the country continue to give courses in airphoto interpretation and photogrammetry, with introductory information on other forms of remote sensing data. Intensive practical short courses on the multidisciplinary application of a range of remote sensing techniques are offered by the Ontario Centre for Remote Sensing. The Alberta Center for Remote Sensing gives an annual introductory remote sensing course. The Land Survey Institute of Nova Scotia conducts a comprehensive diploma program for remote sensing technicians.

In the province of Ontario, there have been a number of major developments. First, the Ontario Centre for Remote Sensing (OCRS) has established a combined digital image analysis/automated mapping system, and has developed software to produce the same map format and annotation features produced by manual cartography. OCRS also initiated a program of training in digital image analysis for private companies in Ontario, consisting of formal hands-on training, and access to the OCRS system and expertise for performing commercial projects. The objective of the program is to develop within the Ontario companies a new internationally-marketable high-technology skill. A committee of university professors teaching remote sensing across the province was formed to work toward improving remote sensing teaching facilities, methods and research opportunities. The University of Waterloo, Ontario, in collaboration with the Ontario Centre for Remote Sensing, became the first Canadian university to offer a certificate short-course in remote sensing to individuals already working in a natural resource or engineering field. The course surveys all remote sensing imagery types, with applications of each, and includes intensive hands-on sessions in digital image analysis.

For a fairly complete collection of Canadian remote sensing literature since 1980, I would refer the reader to the Proceedings of the Sixth, Seventh and Eight Canadian Symposia on Remote Sensing.