P H O R		0 1 6	B	Dispatch: 30.4.03	Journal: PHOR	CE: Blackwell
Journal Name	Manuscript No.			Author Received:	No. of pages: 7	PE: Kannan

ISPRS COMMISSION I SYMPOSIUM: INTEGRATING REMOTE SENSING AT THE GLOBAL, REGIONAL AND LOCAL SCALE

ISPRS COMMISSION I, which is concerned with *Sensors, Platforms and Imagery*, led by its President, Professor Stanley Morain of the University of New Mexico, held its mid-term Symposium at the Adams Mark Hotel in downtown Denver, USA from 10th to 15th November 2002. Given that the Denver area houses one of the largest concentrations of companies and agencies engaged in mapping, photogrammetric and remote sensing activities in the United States, this was a very suitable venue.

COMBINATION OF MEETINGS

The Commission I Symposium was just one of four meetings that were combined and held simultaneously. The largest of the others was the *15th Pecora Conference* of ASPRS, this well-known series having started in 1975. The Pecora Conference was itself combined with the *4th Land Satellite Information Conference*, the same arrangement of combining these two meetings having been very successful in 1999, when it was also held in Denver. The second meeting forming part of the overall combination was the *Remote Sensing for Transportation Conference*, organised by the US Transportation Research Board (TRB). This was accommodated as a special technical track within the Pecora-15 Conference programme. The third meeting, arranged by a group of academic staff from the Old Dominion and George Mason Universities based in Virginia, was concerned with *Future Intelligent Earth Observation Satellites* (FIEOS). Partly it held its own programme of technical and poster sessions within the overall meeting and partly it held two technical sessions in conjunction with Working Group I/4 of ISPRS Commission I.

TECHNICAL EXHIBITION

All of this resulted in a major conference with nearly 1000 participants. It also resulted in a large technical exhibition, which was a complete sell-out, taking up all the available space, and had over 50 exhibitors showing their wares during the 2 days over which it was held. Undoubtedly the extensive programme of lectures and workshops and the probability of a large audience resulted in many commercial companies and government organisations deciding to take part in the exhibition. They included many major system suppliers (such as Leica Geosystems, Z/I Imaging, Boeing Autometric, BAE Systems, Applanix, Vexcel, KLT Associates and PCI); the principal suppliers of commercial high-resolution space imagery (Space Imaging, DigitalGlobe, ImageSat International, Resource21); some of the most prominent suppliers of airborne image

data in the United States (such as Intermap and Emerge); and the main US government agencies concerned with mapping, photogrammetry and remote sensing (USGS, NASA, NOAA, NIMA, EPA, USDA). The end result was a most interesting and very informative exhibition. There was plenty to see and discuss and a superabundance of literature to take home and digest.

TECHNICAL AND POSTER SESSIONS

The joint Pecora-15 and Land Satellite Information technical sessions with their programme of lectures were divided into five simultaneous tracks concerned with natural resources; the environment; disasters and hazards; law and policy; and transportation, the last of these tracks being that organised by the TRB, as mentioned above. The ISPRS Commission I Symposium had two or three simultaneous technical sessions, which meant of course that it was impossible to take in all of the presentations given at the Symposium. Unfortunately, only just over half of the papers presented at the Symposium were available in written form on the CD-R supplied to participants. Thus it was not possible to read many of the papers given in the parallel sessions that one could not attend. The Symposium's technical sessions (each lasting 90 min) were organised on the basis of its six working groups, with between three and five oral presentations being given in a single session. In total, 50 presentations were delivered during the 14 technical sessions allocated to the Symposium. In addition, there were two poster sessions at which a further nine papers were presented.

TUTORIALS, WORKSHOPS AND VISITS

The Commission's technical and poster sessions were held on the Wednesday and Thursday, 13th and 14th November. They were preceded by numerous tutorials and workshops held on 11th–12th November, five of which were run under the ISPRS Commission I banner. These included a half-day tutorial on the *Ten Year Remote Sensing Industry Forecast* that is being developed jointly by NASA and ASPRS. The four ISPRS workshops were entitled: *Digital Aerial Systems in a Briefcase*; *Professional Airborne Digital Mapping Systems: An Overview*; *Utilization/Integration of Lidar for Mapping & GIS*; and *Image Acquisition Technologies for Earth Surface Observation & Generation: Reliability, Accuracy & Comparative Costs*. The first of these four workshops was a half-day event; each of the other three took place over the full day. The final day of the whole Conference (Friday, 15th November) was divided between technical visits to companies based in the Denver area and a full day "Classified Session" on *Innovative Government Applications of Satellite Imagery* that focused on "Homeland Security". However, this last session was restricted to those holding American passports and having the appropriate security clearances.

WORKING GROUP I/1

WG I/1's official title and remit is to *Define Standards for Sensor Parameters*. To my mind, this overlaps heavily with the activities of WG I/2, which is concerned with *Sensor Calibration & Testing*. So, at the Symposium, only a single session took place under the WG I/1 heading. This was concerned exclusively with *Direct Georeferencing of Airborne Imagery* and contained five presentations. The first was given by Karsten

Jacobsen of the University of Hanover and dealt with both the theoretical aspects of direct georeferencing of airborne frame imagery and with the results achieved in practical tests using test data. These data-sets had been supplied by the OEEPE and by the Hansa Luftbild company, having been produced using aerial metric film cameras to which IMU devices had been attached. Mohamed Mostafa of Applanix then spoke about the quality control (QC) of the direct georeferenced data produced using his company's POS/AV system. This included the QC of the GPS data (monitored using national reference networks) and the measured inertial data and the QC of the overall system using photogrammetric methods. It does seem that, although the IMU/DGPS combination provides data of a quality that is sufficient to carry out the direct orthorectification of imagery, it still does not provide orientation data that is accurate enough for the setting up of parallax-free stereomodels for stereocompilation and DEM work. Thus an aerial triangulation operation that is referenced to a suitable network of accurate ground control points is still necessary with the IMU/DGPS data being used as valuable auxiliary data.

Next, G. Kimm of Emerge described his company's recently introduced Digital Sensor System (DSS) which comprises a specially modified Contax frame camera equipped with an $f = 55$ mm lens and a 4000×4000 CCD areal array sensor from Kodak, together with a DGPS/IMU installation. A number of these digital frame cameras have been built for use in Emerge's fleet of light aircraft to replace the small-format Kodak 420/460 series of digital frame cameras used previously. His presentation included the results of accuracy tests carried out over a test site in Florida. Bruce Wright from the University of Calgary then gave a short presentation on his preliminary work concerned with the direct georeferencing of images acquired using a thermal (LWIR) video frame camera which is to be used to identify and locate hot spots within forest fires. Finally Steve Schultz of the Pictometry company outlined the methods used with DGPS/IMU data to locate and rectify oblique airborne digital frame photography, including the results of tests carried out in the San Francisco area.

WORKING GROUP I/2

This working group is concerned with *Sensor Calibration and Testing* and had the largest number of presentations (15) given at the Commission I Symposium. They fell conveniently into two parts. The first part, given over two successive sessions on the Wednesday, comprised 8 presentations concerned with the radiometric and geometric calibration of spaceborne imagers using in-flight calibration procedures. On *radiometry*, the specific imagers that had been calibrated included the SPOT-5 HRG and HRS pushbroom scanners (reported by Breton of CNES) and the IKONOS scanner (reported by Brown of Space Imaging). The calibration of the SPOT-5 imagers consisted of a mixture of pre-flight laboratory procedures and in-flight measurements using stellar sources, followed by tests carried out over terrain test fields. The IKONOS calibration used stellar sources only. A third paper, by Smith of Boeing, concentrated on the radiometric calibration procedures using ground-based spectro-radiometers to calibrate the images acquired by airborne multi-spectral and hyperspectral line scanners. These operations were carried out in support of the proposed constellation of satellites equipped with multi-spectral scanners for agricultural monitoring to be launched by the Resource21 company (which is part-owned by Boeing).

On *geometry*, the spaceborne imagers that had been calibrated were the MISR multi-angle stereoscanner mounted on NASA's Terra satellite and used for 3D measurements of clouds (reported by Jovanovic of NASA/JPL); the IKONOS high-resolution flexible-pointing pushbroom scanner (presented in two separate papers by Dial and Grodecki of Space Imaging); and the imagers mounted on the German Bird micro-satellite (by Schuster et al. of DLR). Intriguingly the last included a modified version of the WAOSS-B stereoscanner, originally designed for use on the Mars-96 mission and which is similar to the HRSC-A series of airborne three-line pushbroom scanners developed by DLR.

The second part of the WG I/2 programme comprised seven papers given in two sessions on the Thursday under the title *Calibration & Characterization: Proposed Standard Processes*. The contributors were all from US government agencies (NASA and USGS) and cooperating universities (Arizona and South Dakota State). As I was participating in other sessions during these two periods and the papers have not been provided in written form, I am unable to report on this topic.

WORKING GROUP I/3

I did, however, attend the session on *Lidar Systems & Performance* which was the only session run by this working group, which is concerned with *Active Sensor Systems*. This was a very good session with excellent contributions from two of the major lidar system suppliers (Leica Geosystems and Optech) and one concerning an in-house system, designed, built and operated by a commercial air survey company (3Di). The three speakers, Ron Roth of Leica, B. Gutelius of Optech and Verlin Fisher of 3Di, all concentrated on the matter of capturing the multiple return signals resulting from each lidar pulse emitted by the airborne laser scanner and on the analysis of their intensities and waveforms. The current concentration on these matters is to enable the height and other characteristics of the vegetation canopy to be established, besides the (bare earth) terrain elevation values. We were told that this type of multiple return intensity and waveform analysis is in its infancy, but shows considerable promise!

WORKING GROUP I/4

As noted above, the first two sessions of this working group, concerned with *Advanced Sensor Systems*, were held jointly with the FIEOS meeting. The first of these was concerned with future satellites. The contributors concentrated on new types of imaging sensors where the processing of the image data would be carried out on board the satellite. Also the imager would adapt itself to the currently prevailing space environment, based on the results of cloud sensing and the monitoring of the space plasma environment. The second joint session was devoted solely to the presentations of a group of Chinese scientists on various aspects of a proposed SAR cluster system. Personally I found the presentations made during these two sessions to be of an overly general nature.

By contrast, the third (purely WG I/4) session was concerned with very specific proposals and designs for future imaging satellites and was much more interesting. J. Niecke et al. from Japan outlined their concept for a regional coastal zone imaging and mapping system. Even more interesting was the proposal by Guy Seguin and Ralph Girard of the Canadian Space Agency (CSA) for the building of a small

(400 kg) mini-satellite equipped with an L-band SAR that would carry out an interferometric SAR tandem mission in combination with the PALSAR imager mounted on the Japanese ALOS satellite that is currently scheduled to be launched in 2004. The PALSAR would act as the main illuminator of the Earth's surface, while the Canadian mini-satellite, equipped with a membrane antenna to keep its weight down, would act as the passive receiver system. This innovative proposal would have the objective of generating a DEM for the polar regions that have not been covered by the Shuttle Radar Topographic Mission (SRTM) operated from the Space Shuttle in February 2000.

Another very interesting proposal for a highly specific mission was that designed for the monitoring of Brazil's Amazon region which was presented by Rudorff et al. of INPE (Brazil's National Institute for Space Research). This would also use a small (400 kg) mini-satellite placed in a very low (±5°) orbital inclination. The use of such a near-equatorial orbit would result in the satellite passing over the Amazon region several times per day. The satellite would be equipped with an optical (VIS/NIR) three-line pushbroom stereoscanner producing images with a 40 m ground pixel size together with a second pushbroom line scanner operating in the MWIR ($\lambda = 3{\cdot}4$–$4{\cdot}2$ μm) region and producing images with a 500 m ground pixel size. The final proposal was presented by T. LeToan of CNES, France and would involve the use of a very long wavelength (P-band) SAR for a biomass monitoring mission (BIOMA-SCA). In total, the various proposals were most interesting and thought-provoking: in my opinion, really innovative.

WORKING GROUP I/5

WG I/5 is concerned with *Platform & Sensor Integration* and is co-chaired by Jacobsen (Hanover) and Ismael Colomina of the Institute of Geomatics of Catalonia. It could be argued that the session of *Direct Georeferencing* held under the auspices of WG I/1 should, in fact, have formed part of the WG I/5 programme. However, there were two other closely related sessions that were indeed run by WG I/5. The first of these was called *Sensor Integration* and was chaired by Colomina. In fact, he also presented the first paper describing two IMU/DGPS systems for remote sensing and the associated software that had been developed in his Institute in cooperation with various partners in Spain and Brazil. Daniela Poli from ETH Zurich then described a general model for use with the stereo-imagery produced from three-line pushbroom scanners and gave the results of accuracy tests carried out with the Japanese Starlabo (airborne) scanner and the MOMS-2P (spaceborne) scanner that was operated on board the Russian MIR station. Another closely related paper concerned with the georeferencing of line scanner imagery was presented by Muller and colleagues from DLR. The resulting RECTIFY software was tested using imagery from various airborne multi-spectral line scanners (ROSIS, DAIS-7915 and Daedalus 1256) as well as DLR's MOMS-2P spaceborne stereo-imagery. Finally one of Jacobsen's colleagues, Helge Wegmann, described further tests of automated aerial triangulation and bundle block adjustment procedures with auxiliary IMU/DGPS data, again using the OEEPE data used by Jacobsen.

The second session, chaired by Jacobsen, carried the title *Geometric Capability of High Resolution Earth Observation Systems*. The first paper, given by Jacobsen himself, presented an overview of the various mathematical models that have been

used with the different imagers—perspective and panoramic film frame cameras and pushbroom line scanners—that have been mounted on spaceborne platforms. He then reviewed the results obtained from these different imagers during the extensive series of tests carried out in Hanover over many years. H. B. Hanley, T. Yamakowa and Clive Fraser from the University of Melbourne contributed the next paper. This provided the detailed results of testing the use of (i) rational polynomial functions; and (ii) the affine projection model, with IKONOS Geo imagery over various test areas in the United States and Australia. The final paper in the session was given by Christoph Dorstel of Z/I Imaging (again in association with Jacobsen!). His paper was concerned with the procedure needed to convert the four individual low-oblique pan images generated by the new DMC airborne digital frame camera into a single virtual image having a perspective projection. The procedure has been tested successfully with DMC images over a test field in south-west Germany. It was a very interesting session!

WORKING GROUP I/6

WG I/6 is charged with the area of *Airborne Optical Sensor Systems*. Again it had two technical sessions. The first covered *Large Format Digital Camera Technology*; the second, entitled *Digital Airborne Cameras*, ran on directly from the first. Thus they can be considered together. The initial presentation was delivered by Brian Gorin of BAE Systems (formerly Fairchild). I had heard this before at the FIG/ASPRS meeting held in Washington in May, but was delighted to hear it again. The company's new electro-optical framing camera uses a 9200×9200 pixel (= 85 Megapixels) CCD areal array having pixel sizes of $8{\cdot}75 \times 8{\cdot}75$ μm. Its development as a digital panchromatic frame camera has been sponsored and largely paid for by the US Navy. It gives a very high framing rate (2 frames per second) and features differential image motion compensation (IMC) for use with the oblique imaging needed for reconnaissance purposes. A DGPS/IMU unit can be added for use in mapping applications. It really represents the outer limit of airborne digital frame camera development at the present time. In addition, two presentations were made (one in each of the two sessions) by David Fuhr of Airborne Data Systems. Again I had encountered this at previous ASPRS meetings, but it was interesting to hear about its most recent developments and applications. His company's Spectra-View system makes use of multiple small-format digital cameras with parallel optical axes that are equipped with synchronised shutters to produce multi-spectral images. A ring laser IMU and a GPS provide the airborne platform's position and attitude. A very similar arrangement is used in the DAIS, which was described in another paper by James Lutes. This is another airborne multi-spectral frame camera system, developed by STS in Hawaii and deployed (rather remarkably) by Space Imaging. It comprises four 1000×1000 pixel digital cameras with parallel optical axes placed on a Zeiss T-AS gyro-stabilised mount and combined with an Applanix IMU/DGPS system to provide positional and attitude data. Both topographic and thematic mapping are being undertaken with these different multiple camera systems.

In this context, it was interesting to note also in the technical exhibition the number of simple airborne digital frame cameras that have come into use in the United States, for example with 3Di, Emerge and EnerQuest, mostly in combination with airborne laser scanning (lidar) systems. Most of these digital panchromatic cameras use 4000×4000 CCD areal arrays from Kodak as their imaging sensor. Then we had an

overview paper delivered in his typical flamboyant style by Franz Leberl from TU Graz. Really this should have been given as the introductory paper to these WG I/6 sessions. Finally we had an interesting presentation from T. Yotsumato et al. of the PASCO Corporation (Japan) on the results of accuracy tests achieved with the first two production examples of the Leica ADS40 airborne pushbroom line scanner. It transpired from the paper that Leica have delivered these two ADS40 scanners to PASCO with substantially different line patterns (in the one case, with forward pointing RGB lines and in the other, nadir pointing RGB lines) which means that, in the latter case, there are no nadir pointing lines in the three-line panchromatic scanner. Interesting though it was, it would have been very much more sensible to have included this paper with the other line scanner papers covered in WG I/5 and to have transferred Dorstel's paper on the DMC framing camera (given in the WG I/5 programme) into the WG I/6 sessions. Indeed it was only too obvious from the discussions during these sessions that some people—both among the organisers, as well as some of those in the audience—still cannot distinguish between digital frame cameras and pushbroom line scanners. They are all "digital cameras" and the all-important metric or geometric aspects are simply being ignored.

There was also a panel discussion on the topic of airborne digital cameras within the WG I/6 programme. However, I was not able to attend this due to a clash with another session.

CONCLUSION

This was a timely and interesting Commission I Symposium. In particular, it fully reflected the fact that airborne digital imagers (both in the form of framing cameras and pushbroom line scanners) and airborne laser scanners represent two of the most important developments concerning practitioners in photogrammetry and remote sensing at the present time. Besides these developments, there were some interesting proposals (rather than actual developments) for new missions and imagers within the spaceborne sector. I much enjoyed and greatly benefited from attending this excellent Symposium.

G. PETRIE
Glasgow