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Autor: Fricker, P. / Walker, S. / Sandau, R.

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LH Systems' ADS40: Photogrammetry goes totally digital

P. Fricker, S. Walker, R. Sandau

LH Systems' brand new ADS40 Airborne Digital Sensor duly took off, on schedule, at the XIXth Congress in Amsterdam last month. Crowds were drawn to LH Systems' booth by a giant inflatable model of the new system, suspended high in the roof space of the exhibition hall. LH Systems complemented their exhibitor activities with numerous technical papers and an exhibitor showcase presentation, all focused on the ADS40. A party and press conference on the Wednesday evening provided an opportunity for journalists to have their questions answered. Words of welcome from LH Systems' President and CEO included an announcement that the first ADS40 units had been sold and would ship early in 2001. The early adopters had chosen! At all stages in the Congress LH Systems emphasized that the ADS40 project had been a joint one with Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre – DLR); booth staff, authors of papers and the messages broadcast on the booth and at the party all included signficant DLR components.

The ADS40 (Fig. 1) is very different from LH Systems' familiar RC30 film camera.

Fig. 1: The eye-catching red and gray livery of the ADS40 emphasizes the long lens housing and the stout handles for lifting the unit in and out of the aircraft.

Am XIX. Internationalen Kongress für Photogrammetrie und Fernerkundung im Juli 2000 in Amsterdam wurde der neue Sensor ADS40 von LH Systems in Zusammenarbeit mit dem Deutschen Zentrum für Luft- und Raumfahrt (DLR) vorgestellt. Wesentliche Merkmale des Sensors ADS40 sind die Realisierung des 3-Zeilen-Prinzips und der Einbezug von weiteren vier multispektralen Zeilen in eine Fokalebene, deren genaue Orientierung im Raum durch die Integration einer inertialen Messeinheit samt GPS von Applanix unterstützt wird. Erstmals in der Photogrammetrie wird eine neuentwickelte, telezentrische Optik verwendet, um die engen Farb- und Filtertoleranzen einzuhalten. Der grosse Öffnungswinkel von 64° senkrecht zur Flugrichtung gewährleistet eine ähnliche flächendeckende Leistung wie es sich die Photogrammeter von den Luftbildkameras gewohnt sind. Damit keine perspektivischen Unterschiede in den drei Farbzeilen entstehen, wurde eine spezielle Anordnung dichroïtischer Filter entwickelt, genannt Trichroïd®, welche das Licht einer Zeile ohne nennenswerten Energieverlust in drei Spektralbänder zerlegt. Grosser Wert wurde bei der Entwicklung auf die Realisierung eines durchgehenden digitalen Datenflusses von der Aufnahme bis zur Datenverarbeitung in der photogrammetrischen Arbeitsstation gelegt. Die Datenformate und das Sensor-Modell sind in einem Infokit offengelegt worden, damit auch andere Programmhersteller die Daten dieses neuen Sensors in ihre digitalen Arbeitsabläufe einbeziehen können.

Lors du XIX^{e} Congrès International pour la photogrammétrie et la télédétection en juillet 2000 à Amsterdam, le nouveau senseur ADS40 de LH Systems a été présenté en collaboration avec le Centre aérospatial allemand (DLR). Les caractéristiques essentielles du senseur ADS40 sont la réalisation du principe des trois lignes et l'intégration de quatre autres lignes multispectrales dans un niveau focal dont l'orientation précise dans l'espace est assurée à l'aide d'une unité de mesure inertiale avec GPS d'Applanix. Pour la première fois en photogrammétrie, on utilise une optique télécentrique nouvellement développée afin de respecter les tolérances étroites pour les couleurs et les filtres. Le grand angle d'ouverture de 64°, perpendiculaire à l'axe de vol, garantit une performance en couverture de la surface semblable à celle des caméras photogrammétriques. Afin d'éviter des différences de perspective dans les trois lignes couleur, on a développé un dispositif spécial de filtres dichroïques, appelé Trichroïd® qui décompose la lumière d'une ligne sans perte d'énergie notable en trois bandes spectrales. Lors du développement, une grande importance a été attribuée à la réalisation d'un flux de données digitales continu, de la prise de l'image jusqu'au traitement des données dans la station de travail photogrammétrique. Les formats des données et le modèle du senseur ont été dévoilés dans un kit info pour que d'autres producteurs de programmes puissent englober les données de ce nouveau senseur dans leurs processus de travail digitaux.

Nel luglio 2000 ad Amsterdam, in occasione del XIX Congresso internazionale di fotogrammetria e telerilevamento, è stato presentato il nuovo sensore ADS40 della LH Systems, in collaborazione con il Centro tedesco per l'aeronautica e la navigazione spaziale (DLR). Le caratteristiche particolari del sensore ADS40 risiedono nella realizzazione del principio a 3 righe e del coinvolgimento di altre quattro righe multispettrali su un piano focale, il cui orientamento nello spazio è appoggiato dall'integrazio-

ne di un'unità di misura inerziale con GPS di Applanix. Per la prima volta nella storia della fotogrammetria si è utilizzata una nuova ottica telecentrata che mantiene le strette tolleranze di colori e filtri. L'ampio angolo di apertura di 64° perpendicolare alla direzione di volo garantisce delle prestazioni estese a tutta la superficie, come quelle delle macchine per le riprese aeree a cui sono abituati i fotogrammetrici. Affinché nelle tre righe cromatiche non ci siano delle differenze di prospettiva, si è provveduto ad inserire uno speciale allineamento con un filtro dicroitico, chiamato Trichroïd®, che dissocia la luce di una riga in tre bande spettrali, senza rilevante perdita di energia. Si è data grande importanza allo sviluppo di un flusso costante di dati digitali, dal momento della ripresa a quello dell'elaborazione dei dati nella stazione fotogrammetrica. I formati dei dati e il modello dei sensori sono stati resi accessibili in un kit informativo in modo tale che anche gli altri produttori di programmi potessero riprendere nel loro operato i dati di questo nuovo sensore.

The three-line-scanner concept on which the new product is based has been explained in numerous papers over the last two years. The concept, first proselytized by Dr. Otto Hofmann in the 1970s, has been used by DLR in a number of successful spaceborne and airborne imaging systems.

Panchromatic and spectral band filters

Arranged on the focal plane (Fig. 2) are three linear CCD lines capturing panchromatic information in views forward, nadir and backward from the aircraft. It has been shown that these three views provide sufficient information for full photogrammetric resititution. In the solution specially developed for the ADS40, each panchromatic sensor is in fact two linear CCD arrays, each of 12,000 cells, staggered by half a pixel (3.25 µm). Also on the focal plane are four further arrays, each 12,000 cells, to acquire multispectral information. The filters in the ADS40 provide the following sensitivities for these multispectral bands:

Band	λ (µm)
Panchromatic (trapezoidal)	465–680 (at λ = 50%)
Red (rectangular)	610–660
Green (rectangular)	535–585
Blue (rectangular)	430–490
Near infrared (rectangular)	835–885

These multispectral bands, in conjunction with the 24,000 pixels in the panchromatic bands, have prompted LH Systems' claim that the ADS40 will combine the accuracy of photogrammetry with the insight of remote sensing – for the first time. The photogrammetric side is well taken care of with the long linear arrays in conjunction with a lens with a Field of View (FoV) across track of 64° providing excellent swath width and the resulting area coverage. The limiting factors in a sensor of this type are the read-out time of the arrays, which is around 800 Hz in the ADS40 and the aircrafts' speed over ground. At a normal flying speed over ground of 200 kts (370 km) the ground sample distance (GSD) is 15 cm. The broad coverage represents continuity from the film camera line and is compatible with new high performance LIDAR systems too.

The output of a line-scanner device has a familiar, «jumbled» appearance, as the ground footprints of the lines are not parallel to one another owing to the movement of the aircraft. The raw, or Level 0 data in the satellite parlance adopted by LH Systems in their explanations in Amsterdam, can be rectified using position and attitude data for the aircraft (Fig. 3), supplied by a specially designed Position and Orientation Systems from Applanix Corporation.

Rectification of images from the engineering model

Interestingly, the same process takes care of any discrepancies in the advance between strips caused by variations in the forward motion of the aircraft, i.e. there is no need for forward motion compensation in the traditional sense, merely for the correct processing of the scan lines actually obtained. The resulting Level 1 data is monoscopically and stereoscopically viewable by humans and software alike, so a triangulation process can be invoked, using a variant of LH Systems' ORI-

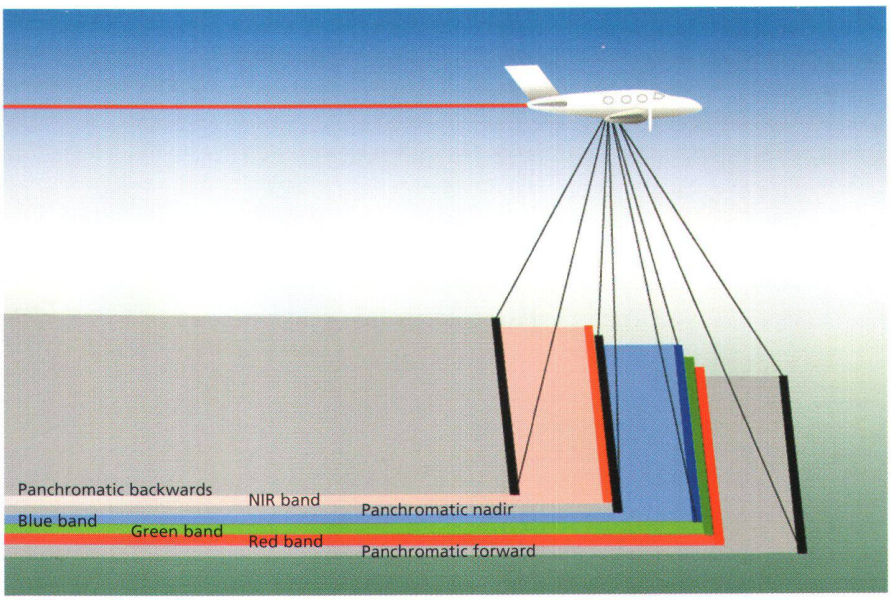


Fig. 2: The layout of the focal plane of the ADS40 provides three panchromatic and four multispectral sensor lines.

Original strip (without gyro stabilization)

Rectified strip

Fig. 3: Generation of Level 1 data from characteristic Level 0 data using data from the Position and Orientation System from Applanix: this success of the rectification process is clear from this imagery over Berlin.

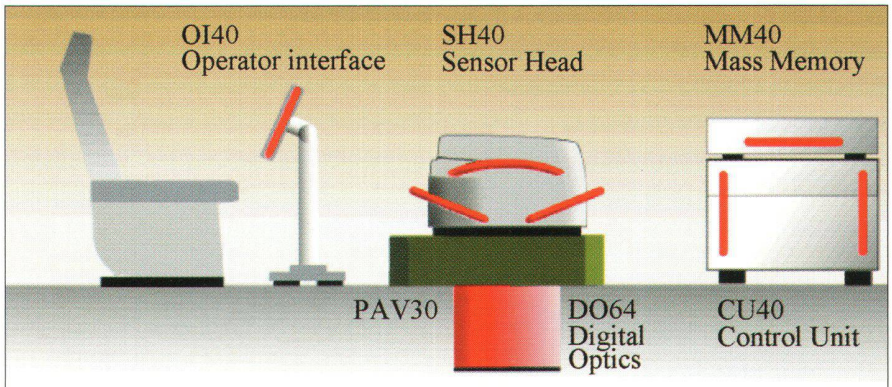
MA product. Though the Level 1 data is used to initiate this process, the final triangulation results can be applied to the Level 0 image data so that as little information as possible is lost through resampling. Thereafter, data can pass to conventional digital photogrammetric processes, for example feature collection or DTM generation by image matching followed by orthophotos and mosaics (Level 2 data).

The elegant camera housing protects complex camera components surrounding the focal plane. On the one hand sophisticated electronics deliver compressed data from all channels to the onboard computer. The inertial measurement unit of the POS is rigidly mounted on the focal plane. Below the focal plane is located the ADS40's lens, a brand new design characterized by its telecentric properties. The multiple components of this lens are ground and arranged such that the light rays emerge from it to intersect with the focal plane at right angles, ensuring optimum performance of the filters. In common with the latest generation of lenses for the RC30 film camera, the lens of the ADS40 delivers similar performance of around 150 lp/mm even at maximum aperture of f/4. Furthermore, an ingenious trichroid device divides incident light into its red, green and blue components, using cascaded dichroitic beam splitters so that no energy is lost. This means that the registration problems characteristic of line-scanner solutions, where color composites can have color fringes since each color band images a different part of the terrain surface at any given instant) are eliminated in the visible spectrum. Further innovative components and systems ensure that the performance of the ADS40 is maintained throughout changes of pressure and temperature.

Whilst undoubtedly the most visible and exciting parts of the ADS40, the housing and its contents are but components of a complex system (Fig. 4). The rack-mounted airborne computer includes a removable, top performance, ruggedized mass memory, very necessary since the ADS40 generates about 100 GB of data per hour of flight! System components also include a new touchscreen for control functions during flight, run by Flight and Sensor Control Management System software specially written for the ADS40 but based to some extent on LH Systems' existing ASCOT product for the film cameras.

The photogrammetric community has been awaiting high performance digital sensors for several years. The tremendous advantages of an all digital flowline, with no more chemical film processing or scanning, are well understood.

Yet there are more subtle issues. A simple one is the realization that archiving is



IMU	integrated in Sensor Head SH40
GPS	integrated in Control Unit CU40
FCMS	Flight Control Management System (Software)
POS	Position and Attitude Computer integrated in CU40
PAV30	not part of standard delivery

Fig. 4: Systems components of the ADS40.

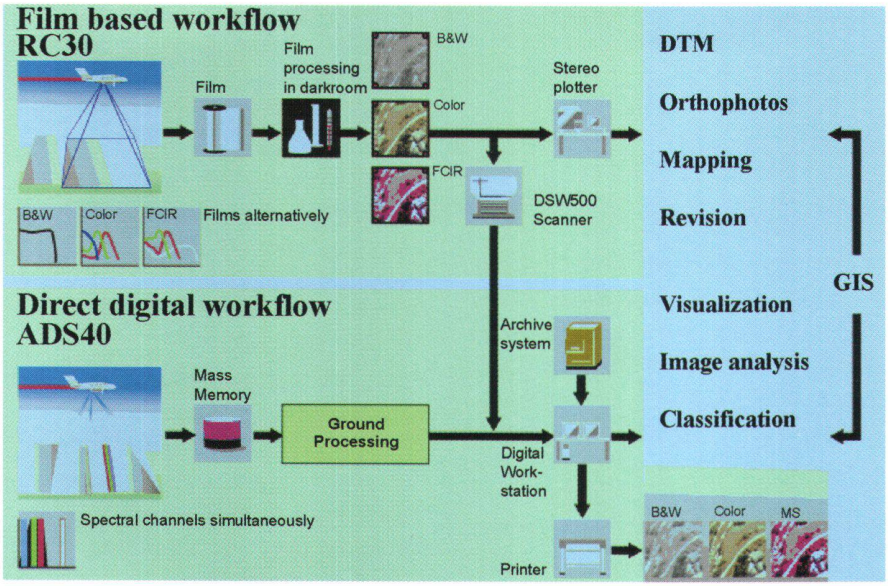


Fig. 5: Comparison of film and digital flowlines.

mandatory. There is no «fall back» to the original film in the can if a digital process goes wrong. Therefore a systematic, modern approach to the storage and cataloging of terabytes of data and metadata can hardly be avoided. Secondly, the geometry of the three-line-scanner is not familiar to all practitioners and some concepts must be understood. There is relief displacement, for example, outwards from the center of each strip but in the case of the nadir sensor there is none along the strip and in the case of the forward and backward sensors the displacement is constant for an object of given height, and does not vary with position along the strip. There is no parallactic angle in the traditional sense, controlled by airbase and principal distance: the stereo angles between the three panchromatic views are functions of the principal distance and the layout of the focal plane – they cannot be varied by project planning. In film imagery with 60% forward overlap, 60% of the terrain appears in three images – the triple overlap – whereas with three-line-scanner imagery every point appears in three images. This means that triple image matching can be used for triangulation and DTM generation, which adds robustness but also computational effort.

Whilst the success of the ADS40 seems assured, with leading RC20/30 customers already expressing interest worldwide and in some cases ready to place orders straightaway, sales levels depend on several factors. Product positioning, for example, must be tackled since LH Systems wishes to continue to sell RC30 film cameras at significant levels for some years to come. A critical one is that in its quest to sell the remote sensing merits of the ADS40, LH Systems must penetrate unfamiliar markets. And another is the importance of LH Systems' competitors implementing algorithms in their software to cope with ADS40 data. This seems likely to happen, as it is of benefit to all parties concerned, and LH Systems has facilitated the process by making freely available an InfoKit containing the tools needed to do so.

So the new era has dawned. The doyen of film camera vendors has introduced a high performance digital sensor, capable of photogrammetric accuracy and coverage on the one hand and multispectral data on the other. The attractions of all digital flowlines are clear. Interest in the product has proved immense. LH Systems' challenges now are to deliver and support the ADS40 with the same competence that has accompanied the film cameras for so many years.

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Peter Fricker
Rainer Sandau
LH Systems GmbH
Heinrich-Wild-Strasse
CH-9435 Heerbrugg
e-mail: fricker@lh-systems.com
e-mail: sandau@lh-systems.com
http://www.lh-systems.com

Stewart Walker
LH Systems LLC
10965 Via Frontera
San Diego, LL CA 97127-1703
USA
e-mail: walker@lh-systems.com