Leica Geosystems Photogrammetric Sensor and Workflow Developments

JUERGEN DOLD, DOUG FLINT, Heerbrugg

ABSTRACT

Over the past two years since Photogrammetric Week '05, there have been significant changes in the airborne photogrammetric imagery marketplace as well as in Leica Geosystems' ability to serve that marketplace. As one would expect, the airborne imagery market demands "better" data, processed faster after collection and available to the end user over faster distribution channels with broader visualization capabilities. Some basic characteristics of this changing marketplace will be reviewed followed by a discussion of how Leica Geosystems has adapted its products and business to serve this market. Of course, the quality of the photogrammetric products going to the end users is only as good as the captured raw data. The Leica airborne sensors developed to acquire the broad range of high-resolution data are leading the way in both the imaging and laser scanning markets. These sensors and recent technology breakthroughs will be reviewed. This includes key aspects of their workflow and how Leica provides the total solution from flight planning to in-flight data capture to preparing the data for careful photogrammetric analysis. Finally, as progress seems to be accelerating year after year in this digital sensor age, some thoughts on future sensor and workflow developments are presented.

1. INTRODUCTION

Since 1925, Leica Geosystems lead the industry in analog airborne film camera technology. In 2001, Leica introduced two revolutionary digital systems – the ADS Airborne Digital Sensor and ALS Airborne Laser Scanner. These sensors, operating subsystems and advanced software workflows now set the industry standard for digital airborne sensor solutions.

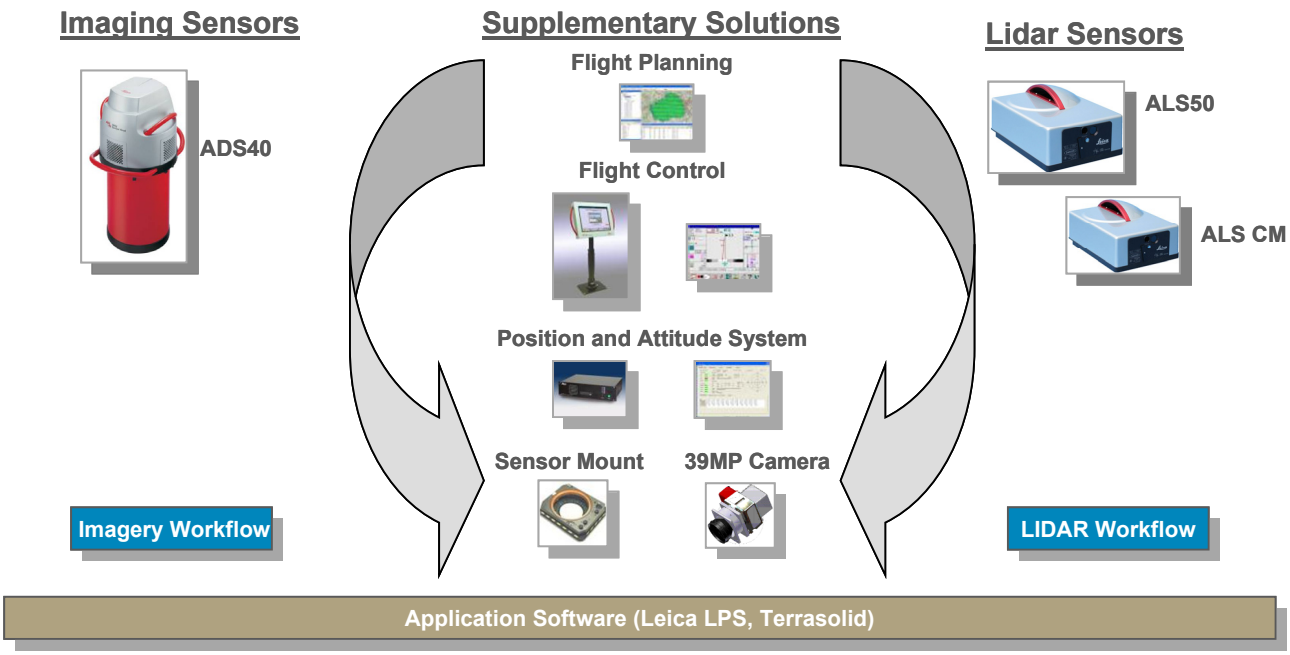

Figure 1. Leica Geosystems Airborne Sensors (ABS) family of products.

The Leica ADS40 2nd Generation SH51 and SH52 Sensor Heads increase aerial survey productivity, maximize area coverage performance and minimize mission time. The Leica ADS40 2nd

Generation Sensor captures all multi-spectral bands simultaneously at the same true high resolution. Providing 5-band, truly co-registered and equal resolution imagery (not pan sharpened) right at data acquisition makes the ADS40 the best system for efficient orthophoto production, feature extraction and remote sensing.

The Leica ALS50-II Airborne Laser Scanner is a laser-based system for the acquisition of topographical data for digital surface models and digital images from return signal intensity data. With leading point density and area coverage, ALS50-II is the most versatile and powerful LIDAR (Light Detection And Ranging) system in the industry. ALS50-II can yield details under tree cover, record data at night and orthorectify imagery using specialized software**.** ALS50-II and the new ALS50-II Corridor Mapper are redefining the power of LIDAR mapping.

Leica Geosystems also manufactures all critical subsystems and software that enhance the operation of its airborne sensors. The IPAS inertial position and attitude system, FPES flight planning and evaluation system and FCMS flight & sensor control and management system are examples of the complete digital workflow, all from one company. No other company with the product line depth of Leica Geosystems has so much control over the hardware subsystems and software workflow so essential to the total mapping solution.

Based in Heerbrugg, Switzerland, Leica Geosystems is a global company with tens of thousands of customers supported by more than 2,400 employees in 22 countries and hundreds of partners located in more than 120 countries around the world. Leica Geosystems is part of the Hexagon Group, Sweden.

2. AIRBORNE SENSORS MARKETPLACE

Two years ago, much discussion concerning the benefits of digital sensors vs. film cameras was still taking place. Large format digital sensors were still only 4 years old then and the technology was just past the pioneering phase. Now, the industry is clearly focused on a digital future and several new LIDAR and imaging sensor entrants attempt to gain a footing in this rapid-paced market. Both Leica Geosystems and Z/I Imaging have announced the end of their film camera production, although the hundreds of film cameras already in the market will continue to play an important imaging role for years to come.

Perhaps the most striking marketplace development has been the battle between Microsoft and Google for dominance in the web-served, consumer driven mapping sectors. This battle has been the spearhead of higher resolution images, 3D visualization capability and the ability to serve, almost seamlessly, terabytes of images to millions of users. A significant influence of this emerging market segment is that satellite imagery has become less appealing than higher resolution airborne imagery where high-detail visualization is required. This is especially true for urban scenes where the highest people density, and therefore highest revenue potential, exists. Satellite imagery is still far more accessible, both in terms of its worldwide coverage and continual updates. There are still many countries that strictly control all collected airborne imagery and rarely allow it to be released to the public. For these countries, only satellite data is available at all.

There are many other market influences that can be mentioned. Traditional city and state mapping agencies and utility companies, for example, have an increasing demand for orthophotos. As digital orthophotos became more affordable, they have become a main planning and management tool. There is also increasing demand for cadastral mapping; e.g., in economic growth regions such as China, India, Russia, and South America plus an increasing need for more frequent updates in these

regions. National security agencies require orthophoto and oblique images for "homeland" protection as well as for hostile territory assessment.

One of the greatest emerging segments is environmental initiatives that will increase the need for remote sensing. Large acquisition projects such as NAIP (National Agriculture Inventory Program) and forestry projects in Canada and the Americas are being used to identify various vegetation changes. Sensors such as the ADS40, with equal resolution in PAN, RGB, and false-color infrared, as well as stable and calibrated radiometry, will be invaluable for these remote sensing applications.

LIDAR has played an increasing role in airborne sensor collection markets. Their precisely georeferenced "clouds of points" quickly produce accurate DTM's and even record PAN intensity values at each of the LIDAR range points. DTM's that used to be generated using photogrammetric techniques from images are now being generated directly from the LIDAR data. Large (national), medium (county) and small (urban or engineering) areas, as well as utility corridors, are all expanding their requirements for LIDAR data. The need to quickly assess the impact of environmental catastrophes (floods) using more affordable DTM's from aerial scanners increases the need for LIDAR collected point clouds. Rapid response needs in military and security applications will further increase the utilization of aerial scanners with their rapid response and night flight capabilities.

Finally, the capabilities of image processing photogrammetric and remote sensing software have continued to expand rapidly. Leica Geosystems Geospatial Imaging Division is a major player in all of these fields, with its Leica Photogrammetry Suite (LPS) and Imagine flagship software products. Primary focus is on feature extraction, automated data processing, processing speed, 3D visualization, enterprise and consumer imagery delivery and many other feature and performance improvements.

3. LEICA GEOSYSTEMS AIRBORNE SENSORS (ABS) MARKET AND TECHNOLOGY COMMITMENT

Since Photogrammetric Week '05, Leica Geosystems has continued hardware, software and workflow developments to maintain its leadership in airborne sensor technology. Leica Geosystems and its parent company, Hexagon Group, are heavily invested in measurement technology. The product family ranges from micron-level machine control to sub-millimeter-level surveying to millimeter-level high-definition (scanned) survey to centimeter-level resolution of its airborne sensors. All of these applications will ultimately move toward utilization of point cloud technology to accurately measure and model in a 3D environment. The hardware technologies used to acquire the point clouds for each application, as well as the software used to process the data, form a set of sophisticated core technologies that can be applied over all of the applications.

Looking first at hardware development, at Photogrammetric Week '05, the IPAS10 inertial position and attitude system was announced. Now, it is exclusively used in all new Leica airborne sensors and is gaining success as a standalone product. The ADS40 Airborne Digital Sensor performance has been dramatically enhanced through incorporation of the new tetrachroid beamsplitter and several other performance improvements. The ALS50 Airborne Laser Scanner has tripled its pulse rate over the same time frame, and has added a Multiple Pulse in Air (MPiA) capability that effectively doubles available pulse rate under certain conditions. In addition to those two "flagship" product lines, Leica Geosystems has just announced the RCD105 39-Megapixel Medium Format Digital Camera. These developments are a small sample of recent Leica Geosystems' technology breakthroughs that clearly show Leica's continued commitment to this marketplace. The

breakthroughs will be reviewed in the following product sections. No other company has a similar commercial airborne sensor product line or a geospatial measuring technology breadth.

Leica's software development efforts have expanded the FPES flight planning and evaluation tool and FCMS flight & sensor control and management system capabilities for operation of ALS50 and virtually any other airborne sensor. Additionally many improvements have been implemented to the workflows of each of Leica's systems and associated subsystems. Many of these developments are also described below.

All of the developments are focused on enhancing customer productivity, improving sensor performance and automation, and expanding the applications addressed by these sensors. All Leica Geosystems Divisions remain committed to serving traditional markets demanding photogrammetric technology as well as to preparing for future new markets driven by the need for 3D visualization and measurement.

4. ADS40 2ND GENERATION

The ADS40 with the sensor heads SH51/52 and SH40 is still the only large format digital imaging camera capable of providing native resolution in panchromatic, true colour and colour infrared images. With the exception of mid-format digital cameras, other patching large format digital cameras still have to resort to additional resampling and pan-sharpening steps. These steps reduce image quality and make its use for remote sensing applications questionable. Figure 2 shows a complete set of geo-referenced and perfectly co-registered panchromatic, colour-infrared and true colour images taken on the same flight and all at the same 10cm resolution.

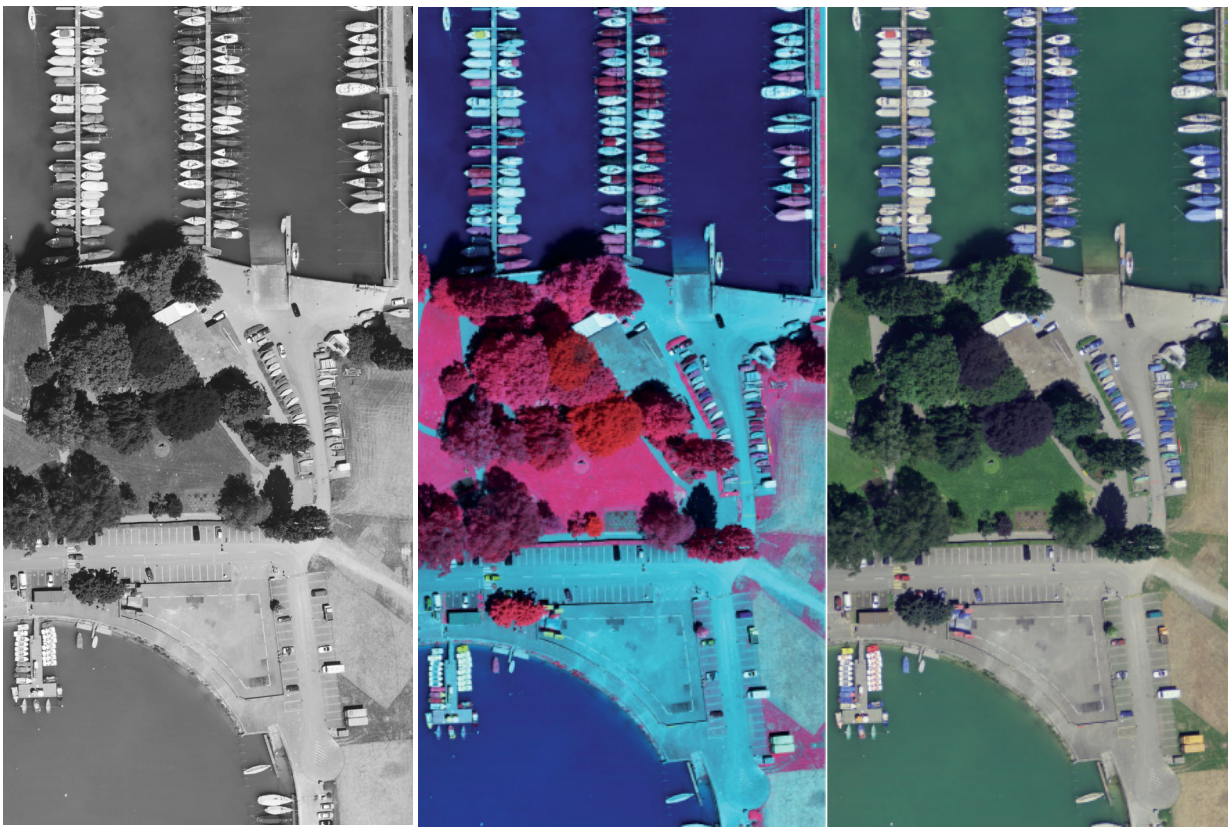

Figure 2. ADS40/SH52 co-registered Pan, RGB and CIR images. Romanshorn, GSD=10cm, Flying height = 1000m.

Since the ADS40 introduction to the market in 2001, more than 50 are in use worldwide producing digital large format imagery and image strips in great quantities. This pioneering step generated a lot of interest within the geospatial community. The overwhelming acceptance of this new technology has proven that large format sensors generate a good return on investment and that "airborne digital" is here to stay. Only 6 years after the introduction of the first generation, the ADS40 2nd generation was introduced and is defined by two new sensor heads. The new ADS40 sensor heads SH51 and SH52 are designed around a unique beamsplitter device, which closely co-registers four spectral bands - all in equal native resolution. Together with an increased signal to noise ratio, new applications are happening and the bar is raised for multi-band, high-resolution airborne imagery for remote sensing and photogrammetry. The SH52's in-track, four-band stereo imaging capability redefines large format sensor performance standards.

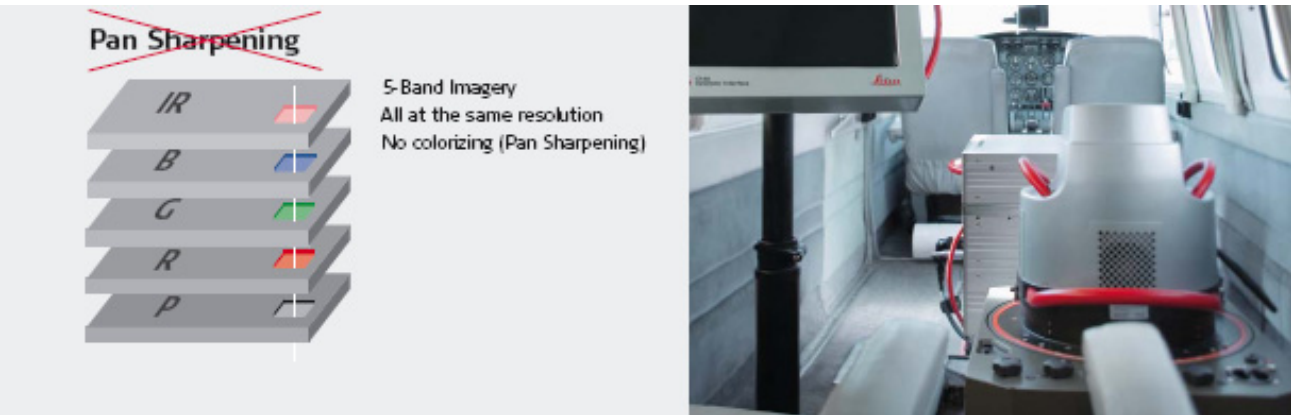

Figure 3. ADS40 2nd Generation Airborne Digital Sensor perfectly coregistered band concept and in-aircraft configuration.

Due to its radiometrically stable construction, the ADS40 sensor is capable of making images for cartography as well as for remote sensing applications. For the increased size of current projects, for sensor fusion, as well as for change detection purposes, it is necessary to produce comparable images for different flight conditions (weather, camera system, etc.). This is not possible with classical film cameras. Comparable images require absolute radiometric calibration of the imaging system, before atmospheric correction, reflectance calibration and BRDF correction can take place.

Leica GPro is the main software tool used to download and ground process ADS40 imagery. It provides the functionality to generate geo-referenced and ortho-rectified images from the recorded imagery and positioning data. GPro also allows automatic point measurement for triangulating ADS40 imagery.

Leica GPro ground processing software includes a multiplicity of great processing features to improve digital airborne image deliverables, thus saving time in the post processing step of the imaging workflow. It interfaces perfectly with Leica LPS and other well-known photogrammetry software packages.

With the Leica Photogrammetry Suite (LPS), GIS and remote sensing deliverables can be produced easily and efficiently. LPS is a collection of seamlessly integrated software features providing accurate and production oriented photogrammetric tools for a broad range of geospatial imaging applications. In addition to LPS, a wide range of Digital Photogrammetric Workstation (DPW) software in the market is now ready to take the advantage of using the line sensor data for feature and terrain extraction in stereo mode.

5. ALS50-II AIRBORNE LASER SCANNER

The Leica ALS50-II, now in its second generation, breaks all the traditional paradigms: having to choose between rapidly-acquired, high-density data and achieving outstanding accuracy, or having to choose between a compact system and one with high altitude performance. The newest ALS50 allows accurate data collection independent of pulse rate, depending instead only on flying height. The flying height envelope ranges from a helicopter-compatible 200m AGL to 6000m AGL for wide area mapping. This industry-leading altitude and sensitivity performance results from having the largest receiving optics of all LIDAR systems. Additionally, low-noise laser pulses deliver outstanding accuracy, even at 150 kHz pulse rates.

Figure 4. ALS50-II Airborne Laser Scanner.

Leica Geosystems has also introduced its novel Multiple Pulses in Air (MPiA) LIDAR technology. The new, patent-pending technology allows LIDAR systems to operate at twice the pulse rate of conventional systems at any given altitude, allowing system operators to cover twice the terrain at current point densities; or, obtain twice the point density at current swath widths. The fielding of this technology marks the transition of this development from an engineering environment to a production technology. Previously, a LIDAR system would send out a pulse and would have to wait for all the return reflections before sending out the next pulse. With MPiA, another laser pulse can be sent out while returns from a previous pulse are still in transit.

Leica Geosystems has also introduced a new airborne LIDAR system designed specifically for corridor mapping and other large-scale mapping applications. The new system, ALS Corridor Mapper, takes advantage of key technologies from Leica's industry-leading ALS-series Airborne

Laser Scanner systems to satisfy the needs of the lower-altitude LIDAR mapping market segment. Corridor mapping has been emerging as a significant new segment within the LIDAR data acquisition market. Until now, LIDAR service providers in this segment had to either buy limited performance systems or purchase a full-capability system with high-altitude performance and cost that may not be needed.

The ALS Corridor Mapper is an ideal solution for both new entrants and experienced firms needing a production instrument. It satisfies all of their performance needs - high point density and high accuracy all the way up to 1000m AGL - while keeping acquisition costs in line with their needs. The ALS Corridor Mapper can also be enhanced over time, since it is engineered to allow incorporation of the latest MPiA (Multiple Pulses in Air) technology, and can also be upgraded to full ALS50-II specifications.

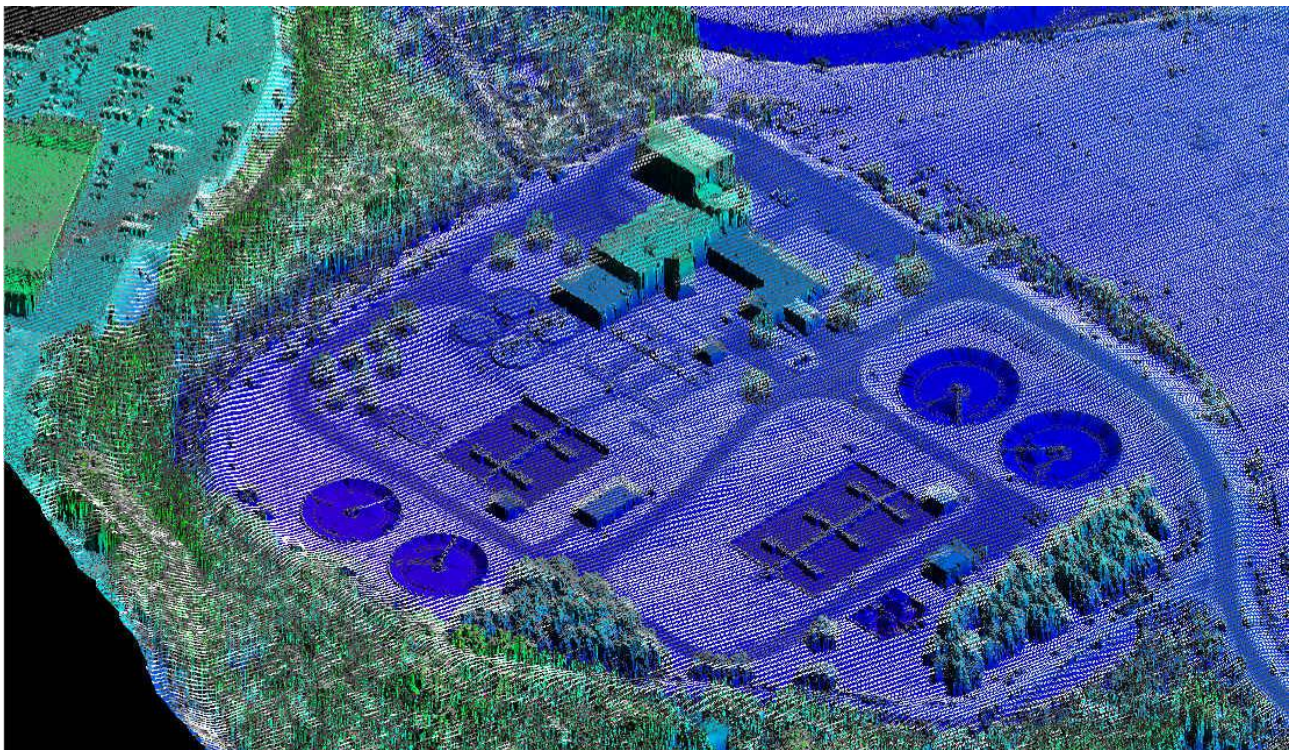

Figure 5. ALS50-II Airborne Laser Scanner sample image acquired at 1250m AGL at 150 kHz pulse rate using MPiA technology.

6. RCD105 39-MEGAPIXEL MEDIUM FORMAT DIGITAL CAMERA

Leica Geosystems now offers a new medium format digital aerial camera system designed specifically for use with its ALS-series airborne LIDAR systems. The new 39-megapixel metric camera system, called RCD105, is designed for "plug and play" connection to Leica's airborne LIDAR systems.

Approximately half of Leica Geosystems' LIDAR owners supply digital aerial photography as part of normal LIDAR survey operations. Until now, users had to rely on third-party camera solutions based on commercial "pro photo" camera products. These previous camera systems can suffer from reliability issues as well as issues related to calibration stability. The RCD105 is designed from the ground up as an airborne digital metric camera solution, and is completely integrated with ALS-series LIDAR products, from mission planning to system operation to image processing.

Figure 6. RCD105 39-Megapixel Medium Format Digital Camera and sample image.

Benefits of this airborne-specific design include complete compliance with all applicable airborne environmental specifications, including temperature, shock, vibration and EMI/RFI. Additionally, a single camera controller is capable of recording data from two camera heads, allowing simultaneous acquisition of natural color and false-color infrared images. No matter which color preference is selected, the RCD105 is available with a variety of lenses and with the industry's fastest frame interval. Another unique feature of this camera system is the user-replaceable shutter assembly, reducing the need for off-site service.

7. IPAS10 INERTIAL POSITION & ATTITUDE SYSTEM

Leica Geosystems has many years of experience with direct georeferencing systems integrated into the Leica ADS40 digital imaging and ALS50 LIDAR airborne sensors. The Leica Inertial Position and Attitude System IPAS10 was first introduced as an OEM system for these sensors. It is now available as a standalone system for a wide range of sensors.

Figure 7. Leica IPAS10 GPS/IMU flight trajectory sensor unit standalone version.

Leica IPAS10 eliminates the need for aerial triangulation on a wide range of mapping projects, reduces the need for ground control and facilitates quality control of acquired sensor data. Thanks to the direct georeferencing of airborne sensor data and the providing of various data such as calculated position, velocity, roll, pitch and heading at high rates and accuracies, IPAS10 saves time and costs in the production of airborne sensor data.

IPAS10 consists of three components: a control unit with an embedded state-of-the art GPS board for high dynamic airborne applications and a universal plug-and-play interface for various IMU types; controller software as the operator's graphical user interface – a user-friendly, interactive and Windows™-based software with all main operation information contained in a single window; and IPAS Pro software which blends IMU data with GPS trajectory information to provide robust, post-mission position and orientation data solutions.

IPAS10 provides a significant reduction in airborne sensor data production cost. It eliminates the need for aerial triangulation for a wide range of mapping projects. Plus, IPAS10 reduces the need for ground control and facilitates data QA/QC.

8. FPES FLIGHT PLANNING & EVALUATION SYSTEM

Geospatial imaging starts with flight planning and ends with the deliverable. An optimized flight plan is the key for cost effective airborne image acquisition. Flight evaluation enables quality control at an early stage in the workflow, and project management considerably increases productivity and cost effectiveness. Leica Flight Planning & Evaluation Software (FPES) covers all tasks in this step in the geospatial imaging chain. FPES fits perfectly into Leica Geosystems' seamless workflow.

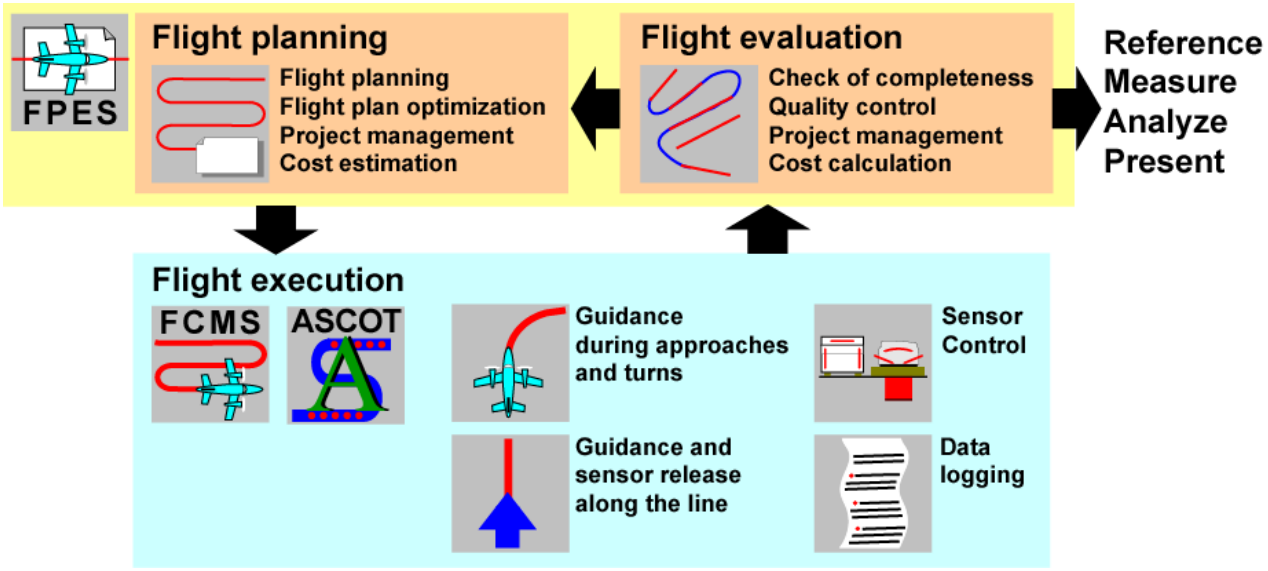

Figure 8. FPES Flight Planning & Evaluation System functional diagram.

FPES provides: cost savings and reduced time for flight planning, proposals, flight reporting and invoicing; seamless data flow from flight planning to photogrammetry; simplified handling of large projects; and an upgrade path from Aerial Survey Control Tool (ASCOT) – Leica's previous flight planning and management tool - enabling import of existing plans. FPES allows efficient flight planning for all types of sensors including the Leica RC30 Aerial Camera System, Leica ADS40 Airborne Digital Sensor, Leica ALS50 Airborne Laser Scanner and other frame, line or ON/OFF sensors. It generates flight plans on all common types of geographic and grid systems and can take DTM's into account to compute area coverage. There is even a corridor mapping feature that splits a polyline automatically for coverage with a minimum number of flight lines. Outputs include: a flight plan database, enabling easy and efficient data handling of large projects; a flight plan output for flight execution with FCMS (described below) and ASCOT; flexible data export for further use of all flight data; perfect data flow to the next processing steps; and data for project management.

9. FCMS FLIGHT & SENSOR CONTROL AND MANAGEMENT SYSTEM

Airborne survey flights have always been a challenge for pilots and sensor operators. The Leica Flight & Sensor Control Management System (FCMS) makes survey flights run more smoothly. A sensor system is controlled and operated by FCMS. It performs all tasks, such as flight guidance, sensor release and sensor monitoring, on a single man-machine interface. FCMS takes control of either a single or multi-sensor system. FCMS starts and stops image data recording or releases frame sensors at the planned positions.

Knowing in-flight which lines are not yet flown and which lines need to be re-flown for various reasons, such as clouds, is important. During flight execution, the operator and the pilot can independently select various views. The optimized flight guidance offers north-up views for project overview and controlling the flight execution progress. The nose-up view is offered for optimized approach and turns with suggested flight path, and the in-line view is offered for precise navigation along the line. If a specific portion of a flight line is missed, FCMS will provide an exact guide to the missing part. In-flight evaluation allows flight execution progress and quality control checking. FCMS stores, in flight, all data required for post-flight mission analysis. This is essential for

optimal management of aerial survey projects, especially for large projects with more than one aircraft used.

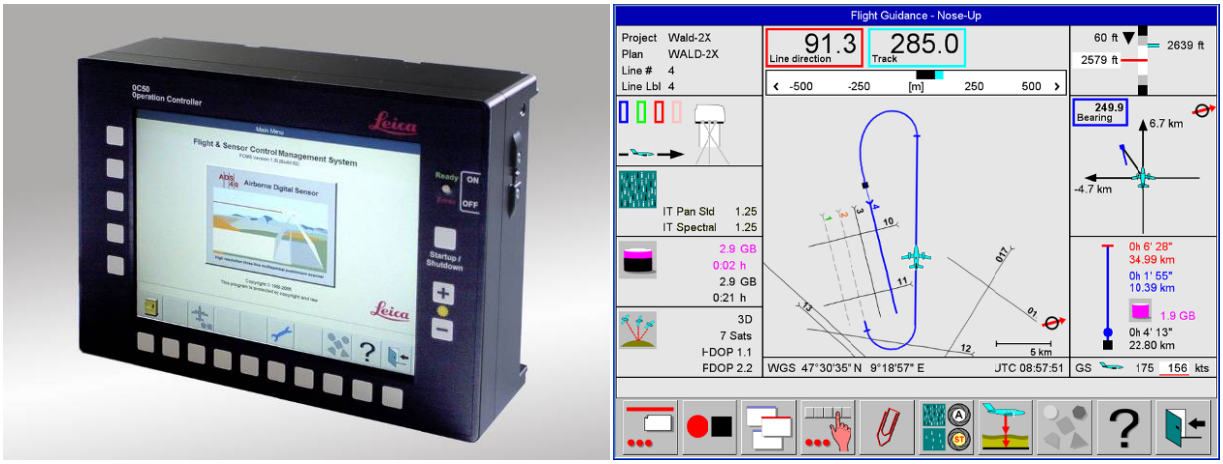

Figure 9. FCMS (Flight & Sensor Control Management System) shows the Pilot and Operator Controller OC50 for FCMS and Flight Guidance screen.

Since the software provides automated operation, user interaction is minimized. Operation is intuitive and novice users are able to operate the sensor after a very short training time. Precise aircraft positioning is an easier task for the pilot due to the sophisticated flight guidance information provided during all phases of the survey flight. Additionally, in-flight quality control considerably increases productivity and cuts data acquisition cost. Careful attention is given to optimize the workflow starting with flight planning and ending with the deliverable data. FCMS tightly integrates flight and sensor control in the entire workflow.

10. WHAT'S NEXT FOR AIRBORNE SENSORS AT LEICA GEOSYSTEMS

Airborne sensor development is proceeding in four major areas: performance, features, workflow, and data fusion. As a market leader in high-end digital imaging and scanning sensors and geospatial imaging software, Leica is in a unique position to assess market needs for technology and workflow improvements. In addition, Leica continually looks for improvements in flight planning, in-flight sensor control and management and sensor mount systems. Leica continues to push the performance and feature envelope in areas such as ADS40 radiometric calibration and ALS50 point density and data smoothness, resulting in an ever-higher quality image product with consistently less manual data processing intervention.

More importantly, Leica is working on several areas of the "pixel carpet" and "point cloud" workflow to further increase accuracy and reduce processing time. These efforts present the greatest potential return on investment gains for our customer base, since flight data acquisition represents only a fraction of overall data production cost. The workflows will also become faster by taking advantage of high-speed and distributed processing. They will become more automated with smarter algorithms for less manual editing and fewer error sources.

Finally, Leica is uniquely positioned in sensor and software technologies to utilize fused data from many imaging sensor (pan, color, NIR, thermal, multi-spectral, hyper-spectral) types plus from LIDAR, SAR and high-definition survey sensors. Technology and markets are moving from two-dimensional maps to three-dimensional, geospatially located point clouds with each point having its

various spectral information “attached”. This will facilitate visualization, feature extraction, and zooming capabilities that will become the future of geospatial imaging applications. Sensor fusion will make available geospatial *information* at a reduced “cost per pixel”. It will also fuel increased demand for airborne sensor data acquisition capabilities for the vast terrain data sets mapped with increasing frequency.

11. SUMMARY

In summary, Leica Geosystems has continued to dramatically improve its airborne sensor hardware and associated software capabilities. The result has been an increase in both system ease of use and number of applications that can be addressed, as well as the speed and accuracy at which data products are produced. The marketplace for high-quality airborne imagery is evolving almost as fast as the technology serving it. Plus, as more quality imagery is delivered to end users – commercial, government and now even consumer – a greater demand is placed on receiving a high-quality and consistent data product.

Leica Geosystems has demonstrated a clear, continued commitment to the airborne sensor market and to the photogrammetric technologies that capture and process the data for the market. With its broad array of sensor and workflow solutions discussed above, Leica Geosystems will remain a leader in photogrammetric science application to imagery and point clouds.