'Photogrammetric Week 05' Dieter Fritsch, Ed. Wichmann Verlag, Heidelberg 2005.

DigiCAM and *LiteMapper* - Versatile Tools for Industrial Projects

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ABSTRACT

Since 1982 IGI has specialised in the development of precise aircraft guidance and sensor management systems for aerial survey flight missions. These developments did result in the *CCNS*, *C*omputer *C*ontrolled *N*avigation *S*ystem, whose 4th generation is in world-wide operations with more than 200 companies. In 1996 IGI introduced *AEROcontrol*, a GPS/IMU(DTG) based system for the determination of the exterior orientation parameters of a sensor. In 2000 *AEROcontrol-IId* was presented with a FOG-based IMU for highest accuracies needed for aerial survey operations.
At the 49th PhoWo IGI presented the *LiteMapper*, a series of affordable *LIDAR Te*rrain *Map*ping systems for creating DTMs/DSMs with fixed-wing aircraft or helicopters. The great advantage was that *LiteMappers* could directly be based on *CCNS/AEROcontrol* technology.
At this years PhoWo IGI introduces a mid-format digital camera, the *DigiCAM-H* with a resolution of 22 Mpixels. The *DigiCAM* has been designed for airborne operations and can be used together with the *CCNS4* and *AEROcontrol* or in parallel with *LiteMapper*.
As a special contribution to the 50th PhoWo, IGI will present the DigiFLY, a prototype of a four-rotor experimental helicopter of the type quadroheli with a digital camera, which is a versatile platform for industrial projects and emergency operations.

1. INTRODUCTION

Within the last five years, dramatic changes have taken place in the aerial survey business. Small scale aerial photography has been taken over more or less by satellites and medium scale aerial photography has been directed to larger scales, black and white is nearly replaced by color. GPS and GPS/IMU technology have set milestones for saving ground control points and making cross-lines unnecessary. Digital cameras, which have changed the market for amateur photography by 99% within the last five years, have taken over the leading role for large format metric aerial camera systems as well.
These large format digital cameras are expensive. For that reason it may be worth thinking about, if, e.g. mid-format digital cameras, can take over a role on providing the information needed. Especially for technical projects as streets/highways/railways, power-lines and pipelines for example, there is no need for an expensive large format digital camera.
Since more than 20 years, IGI has specialized in the development of precise aircraft guidance and sensor management systems for aerial survey flight missions, resulting in *CCNS*, the Computer Controlled Navigation System; its 4th generation is marketed.
Since nearly 10 years, IGI offers a GPS/IMU based system, first developed for lever-arm correction, later on for the determination of the exterior orientation parameters for a sensor at a given instant. The resulting product *AEROcontrol-IId* fulfills the highest demands on accuracy needed.
The own development for *CCNS* and *AEROcontrol* together with years of experience in interfacing different types of sensors build the IGI core competence in airborne sensor applications. IGI used this basis for a development of the *LiteMapper* systems, and a new professional mid-format digital camera, the DigiCAM-H.

2. THE *DigiCAM*, IGI'S MID-FORMAT AERIAL CAMERA SYSTEM

The *DigiCAM* digital airborne camera systems combine modified professional digital cameras with an easy to use graphical user interface for real-time preview capability together with the *CCNS/AEROcontrol*. The cameras can be operated in RGB or CIR mode, respectively.

2.1. *DigiCAM-H* Design

The *DigiCAM-H* system is based on Hasselblad camera components with a modified IMACON 22 MPixel CCD backplane, with 4080 x 5440 pixel at 9 µm size. The *DigiControl* computer with the touch-screen user interface can control several cameras at once. The operator can check quick-views and exposure histograms of the actually taken photos in real time and change all necessary settings of the different cameras. For pre-planned flight missions, the cameras are triggered by the *CCNS4*. The *DigiCAM-H* is prepared for operations together with the *AEROcontrol* system for the determination of the EO-parameters of all images taken. One *AEROcontrol* can be operated together with one, two or four *DigiCAM-H* cameras mounted in a pod. Cameras in RGB mode can be combined with cameras in CIR mode.

Figure 1: *DigiCAM-H* system

For each *DigiCAM-H* operated, an Image Bank stores 850 images in 16 bit color and full resolution, multiple storage devices can be used during one flight mission. For that reason the storage space can be scaled up in steps of 850 images just by using additional Image Banks of 0.72 kg each. The camera can be operated together with several fix-focus, calibrated lenses with electronic shutter. Available are (maximal aperture / focal length):

- 3.2 / 150mm
- 2.2 / 100mm
- 2.8 / 80mm
- 3.5 / 50mm
- 3.5 / 35mm

The modular design of the *DigiCAM-H* enables a change from RGB mode to color-infrared mode within minutes for all noted lenses. If RGB and CIR images shall be taken at the same time, two

DigiCAM systems may be operated within one camera-pod. If a high image repetition time is needed, up to four *DigiCAMs* can be operated in one pod installed in a standard camera mount. The *DigiCAM* system is compatible with all kind of commonly used sensor mounts.
The *DigiCAM-H* has an image repetition time of less than 3 seconds. If photos have to be taken with a higher frequency, two *DigiCAM* systems can be operated in an alternating mode.

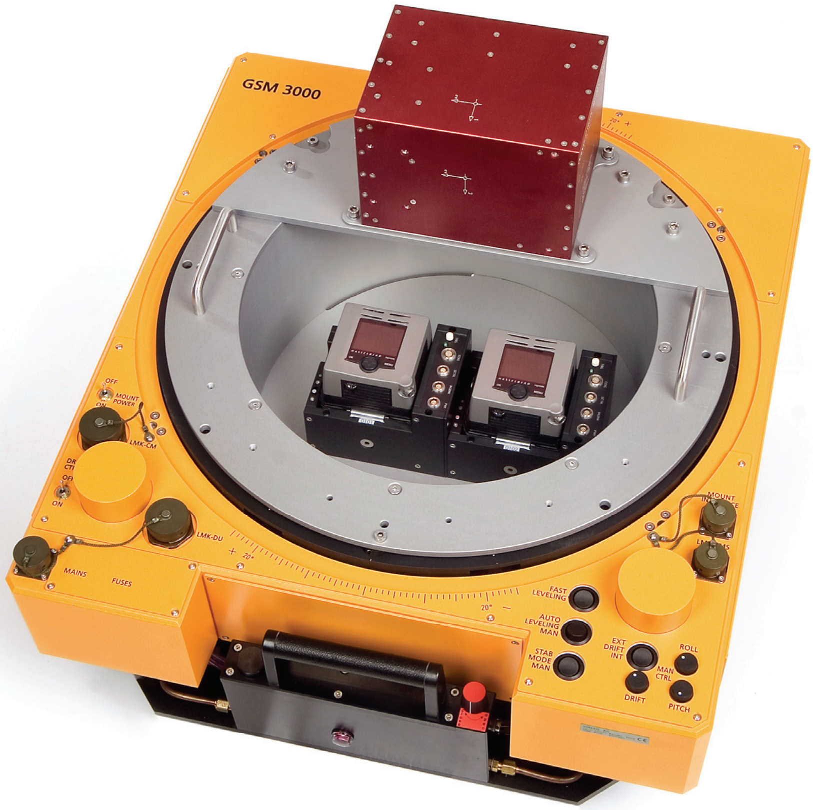

Figure 2: Two *DigiCAM* systems (RGB & CIR) mounted in a camera-pod to be operated in a GSM3000 mount

To upgrade the camera in case back planes with more pixels become available, the digital back can be exchanged without changing the rest of the camera system.

2.2. Targeted Operations

For the operation of a mid-format digital aerial camera, excellent possibilities can be seen in the following fields of application:

- corridor mapping
    - power-line and pipeline surveys
    - roads, highways and rail tracks
    - coast lines
- urban centers, especially big cities with tall buildings
- any small to mid size aerial survey project,
  including rapid response applications.

The advantages of a mid-format camera for corridor mapping are obvious: For a typical corridor project, only the feature in the middle of the corridor provides the wanted information. If a sensor with a very high number of pixels perpendicular to the flight direction collects information far outside the wanted area, this information only costs processing time and storage space without any benefit. An example could be the mapping of a street: For a required Ground Sample Distance of 5cm, the *DigiCAM H* would provide a swath width of 272m which would be sufficient for most applications. A large format digital camera would typically provide a corridor of nearly 600m and more.

For the noted small to mid sized projects with a tight time schedule, the following example may be of interest:
Within the European Union a huge amount of small areas have to be observed with CIR photography for the control of agricultural subventions. These airborne operations are usually executed with a standard 150mm/6inch film camera at a photo scale of 1:30,000 with a comparable GSD of <1m. The flying height is 4.500m and one image covers 47sqkm. Usually the client would like to have the images in his hands on short notice and the final result has to be delivered in two weeks.
The *DigiCAM-H/22* with 35mm lens, a CIR filter and a GSD of 1m will cover 22sqkm at a flying height of 3,900m. But the most important for the client is that he can receive his images on a hard-disc the other day; if necessary together with the EO-parameters for each photo!
The small size and weight of the *DigiCAM-H/22* will allow the operator to use an ultra-light aircraft, which can be operated at the same speed as actually used in single engine piston aircraft but for a fraction of its costs.

Differently from the large format digital camera systems, this mid-format camera works with exchangeable lenses. This means that the camera can operate even under difficult weather conditions under the cloud cover with a wide angle lens. On the other hand, lenses with a long focal length are available to create orthophotos with minimal distortions in urban areas.

Figure 3: *DigiCAM-H*

3. THE *LiteMapper* LIDAR TERRAIN MAPPING SYSTEM

LiteMapper is a series of affordable airborne LIDAR terrain mapping systems for topographic surveys in 3D with fixed-wing aircraft and for 3D corridor mapping with helicopters. The concept of the *LiteMapper* is to provide measurements with highest accuracy in a compact and lightweight package. An installation of the *LiteMapper* inside an ultra-light aircraft is possible. The system can include up to two digital cameras, e.g. one for RGB and one for color-infrared.
Currently, two different camera systems are integrated with the *LiteMapper* (see table 1).

Version	*DigiCAM 14K*	*DigiCAM-H*
Pixels	4,500 x 3,000	5,440 x 4,080
Sensor	CMOS	CCD
Radiometric resolution	R-G-B 12 bit	R-G-B 16 bit or CIR 16 bit
Frame rate	0.6 s – 4 s (depending on the number of photos)	< 3 s
GSD @ 200m corridor width	4.4 cm	3.7 cm

Table 1: *DigiCAM 14K* and *DigiCAM-H* Parameters

The *LiteMapper* is tightly integrated with the *CCNS4* flight guidance system. The *CCNS4* guides the pilot on pre-planned flight lines, operates the LIDAR and triggers the digital camera(s). As a result of this tight integration, a dedicated LIDAR operator is not mandatory. Nevertheless, the systems contain a touch screen display to get real time information about the status of the system, to change the system settings, and to operate the system in manual mode.
Both, LIDAR and digital camera are coupled to the *AEROcontrol* GPS/IMU system to provide the necessary orientation files for the geo-referencing of the LIDAR points and for the "Direct Geo-referencing" or "Integrated Sensor Orientation" of the digital images.
In the following chapter, the newest member of the *LiteMapper* series is described.

3.1. *LiteMapper*-5600 Design

The laser scanner used in the *LiteMapper-5600* LIDAR system is a *RIEGL* LMS-Q560. It is extended by *LMcontrol* and *LMtools* a control and management system for the collected laser data. A sensor control unit for up to 60 hours data logging together with a detached 8 inch TFT touch-screen for data registration, visualization and quality control during the airborne mission are part of the *LiteMapper* systems. The sensors are mounted on shock absorbers, especially designed for helicopter and fixed wing aircraft operations.

The Riegl *LMS-Q560* inside the *LiteMapper-5600* provides a unique feature: it gives access to detailed target parameters by digitizing the echo waveform of each laser measurement [Hug et al. 2004]. After flight the digitized waveforms can be analyzed subsequently off-line.
This approach proves especially valuable when dealing with challenging tasks, such as canopy height investigation or highly reliable automated target classification. For agricultural application this feature opens a complete new field of possibilities.
The *LiteMapper-5600* utilizes the time-of-flight distance measurement principle with infrared light pulses and a rotating mirror scanning system, providing absolutely linear, unidirectional and parallel scan lines. The laser pulse waveform can be extracted with high resolution and precision and can be used for in-depth waveform analysis in post processing. The waveform digitizing principle is illustrated in figure 4:

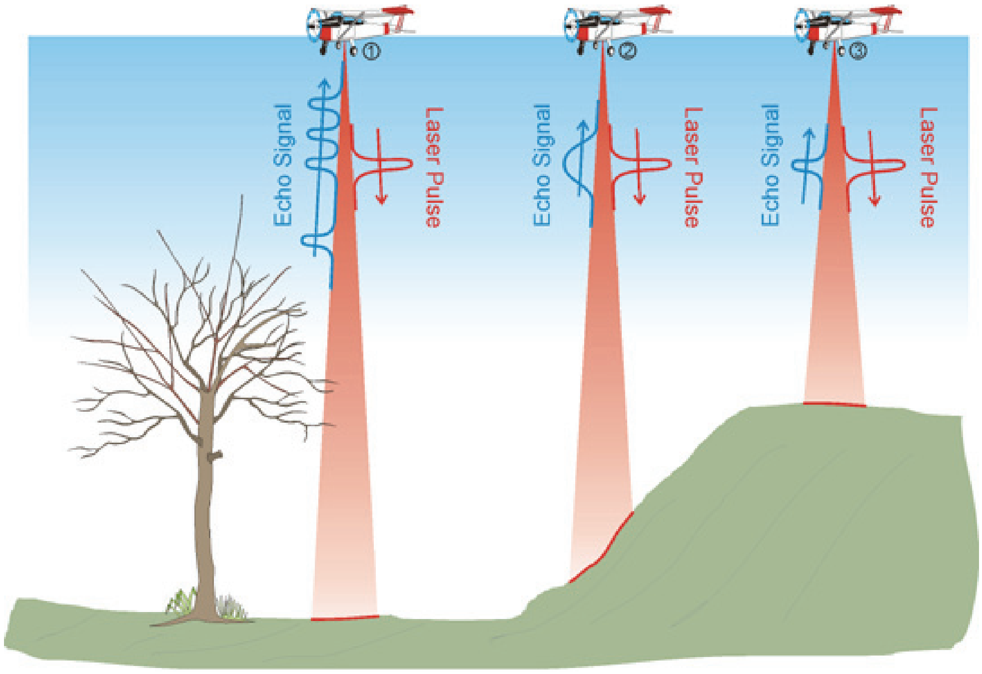

Figure 4: Waveform digitizing principle - Echo signals resulting from different targets [Riegl 2005]

In situation 1, the laser pulse hits the canopy first and creates three distinct echo pulses. A fraction of the laser pulse also hits the ground giving rise to another echo pulse. In situation 2, the laser beam is reflected from a flat surface at a small angle of incidence yielding an extended echo pulse width. In situation 3, the pulse is simply reflected by a flat surface at normal incidence resulting in a single echo pulse with a similar shape as of the outgoing laser pulse.

Measurement range[1)]	≥ 850 m @ ρ = 0.2 ≥ 1500 m @ ρ = 0.8
Measurement accuracy [2)]	± 20 mm
Waveform sampling interval	1 ns
Dynamic range of waveform capture	16 bit
Multi-target resolution	better 0.6 m
Laser pulse repetition rate (PRR) [3)]	up to 100 000 Hz
Laser beam divergence	0.5 mrad
Eye safety class	Class 1
Scan angle range [4)]	±22.5 deg
Scan speed	5 – 100 line scans per seconds
Scan angle accuracy	0.0025 deg

[1)] target size in excess of laser foot print, normal incidence, visibility ≥10 km, PRR <40kHz, ρ gives reflectivity of diffusely reflecting target
[2)] standard deviation, plus distance depending error ≤20 ppm
[3)] user selectable, average measurement rate ≤ 66 kHz @ ±30 deg scan angle
[4)] up to ±30 deg with 90% of maximum measurement range

Table 2: Specifications of the *LiteMapper-5600*

3.2. Targeted Operations

For the operation of the *LiteMapper*, excellent possibilities can be seen in the following fields of application:

- Infrastructure planning and maintenance, e.g. for
  - power lines
  - pipelines
  - railroads
  - highways
- High accuracy flood-plain mapping
- High resolution urban area mapping

Figures 5 and 6 illustrate the capability of the *LiteMapper* to perform high accuracy highway mapping. (In this example, results from the *LiteMapper-2800* are used*)*. On the right side of the right highway lane, groves in the asphalt can be seen. These groves are caused by heavy trucks, which have to drive on the right lane. Figure 6 shows a section through the highway. The grooves have a depth of a few centimeters, but they can clearly bee seen and measured.

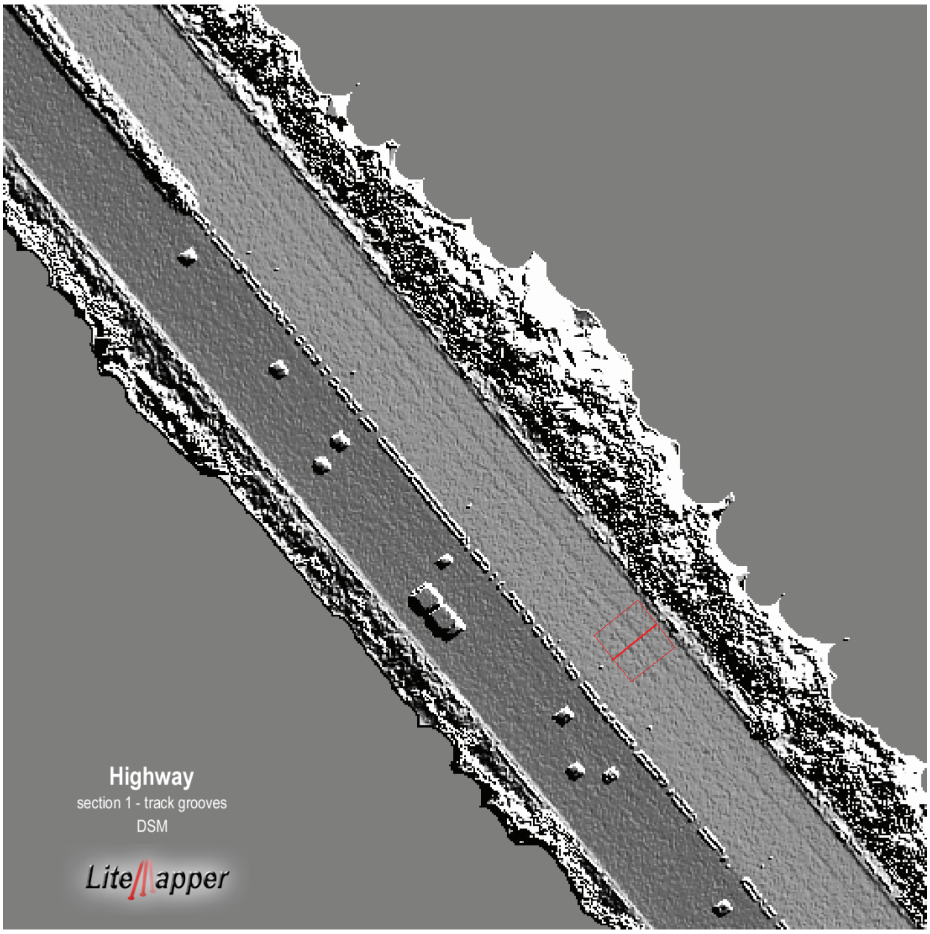

Figure 5: Visualization of a DSM created with the *LiteMapper-2800*

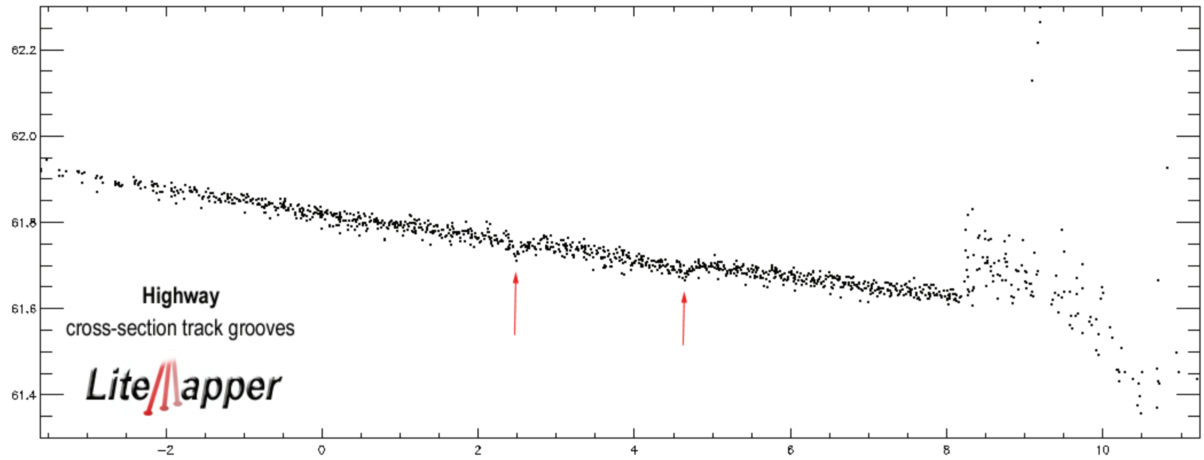

Figure 6: Section through figure 4

The *LiteMapper-5600* with waveform digitization is especially well suited for forestry and agriculture monitoring.

In forestry and agricultural applications the digitized waveform information is valuable for deriving several vegetation parameters: not only tree/vegetation height is available, but also vertical canopy expanse and density, height of second, third, and lower levels of vegetation, and the height and density of ground vegetation. Calculation of timber volume, biomass and other important vegetation descriptors is thus facilitated and made more precise.

4. DigiFLY

For special projects, the need for a portable, flexible reconnaissance system is of great interest. This may be on the occasion of a big flood or earth-quake, to receive an overview on the amount of destruction and to start the needed help as soon as possible.

The inspection of difficult to reach areas, e.g. bridges from underneath, easily can be operated by such a system.

Not for reconnaissance projects only, but for projects, where metric cameras have to be operated, the *DigiFLY* may be an excellent tool. The monthly flights for open-cast-mines or, the documentation of highways accidents can be by a *DigiFLY* system.

Figure 7: *DigiFLY*, a battery powered helicopter of the type quadroheli

For the noted possibilities, a portable quadroheli has been developed for carrying a video sensor or RGB or CIR digital camera. Some specifications of the DigiFLY are:

Gross-weight:	1 kg
Payload:	0.3 kg, e.g. a 7.2 Mpixel digital camera
Endurance:	0.5 hour mission
Range:	0.5 km
Stabilization:	MEMs IMU
Positioning:	GPS
Transportation:	detachable

DigiFLY actually is operated visually or with eyeglasses by hand control via a radio link. The information from the little display of the digital camera operated is given to the eyeglasses together with other information from the system.

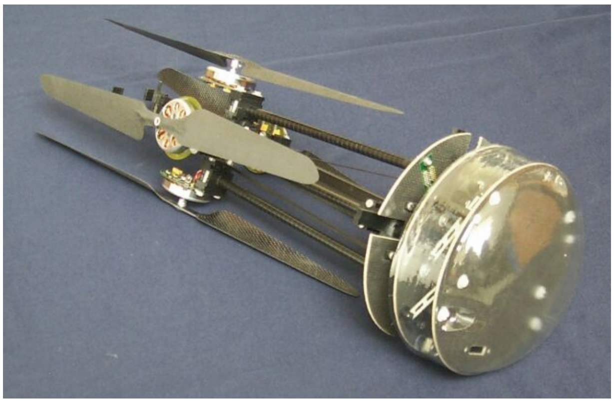

Figure 8: DigiFLY folded for transportation

Figure 9: DigiFLY quadroheli with attached 7.2 MPixel digital camera

5. CONCLUSIONS

IGI has integrated LIDAR and medium format digital cameras to provide complete airborne sensor systems for special applications.
The *LiteMapper* LIDAR system is optimized for corridor mapping with helicopter or fixed wing aircraft and for small to medium sized topographic mapping projects with highest accuracy requirements. The waveform digitizing *LiteMapper-5600* opens new possibilities for forestry and agricultural applications.
The *DigiCAM-H* digital camera system provides a cost efficient solution for small and medium sized photogrammetry projects and corridor mapping. The capability to switch from RGB to CIR and to change between lenses with different focal length makes the *DigiCAM* system a versatile tool for all kind of projects where a large format digital camera can not be used efficiently.
The *DigiFLY* portable quadroheli together with a small format digital camera may be able to close the gap between small aerial survey projects and conventional terrestrial surveying. It opens new variety of applications that can not be overseen, yet.

6. REFERENCES

RIEGL Laser Measurement Systems GmbH (2005): Company Homepage, http://www.riegl.com

Hug, C., Ullrich, and A. Grimm, A. (2004): LiteMapper-5600 – A Waveform-Digitizing LIDAR Terrain and Vegetation Mapping System, IAPRS Vol. XXXVI Part 8/W2, pp. 24 - 29