

# Power Line Mapping: Data Acquisition with A Specialized Multi-Sensor Platform

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## ABSTRACT

Airborne Lidar is a well proven and widely used technology for providing geometrical information for planning, documentation and monitoring of electrical power lines. Besides the exact geometry of the elements, like the position of the poles and the sag of the wires, it provides information about the direct vicinity of the power line. Especially the measurement of position and height of vegetation are important to identify potential risks for safe operation. To improve the interpretability of the Lidar data and to obtain additional information, it became customary to capture aerial photographs together with the Lidar point cloud.

A next step to improve efficiency and flexibility of airborne power line mapping is the combination of airborne Lidar systems with nadir and oblique cameras in an external helicopter pod. The system described in this paper allows the simultaneous capturing of an extremely dense pointcloud together with high resolution photos of the poles from three perspectives (forward, backward and nadir). The sensor system can be mounted to an AS350 helicopter within less than half a day and its flexible layout allows to operate additional sensors like a thermal camera, a CIR camera or a video system with minimal modifications.

## 1. INTRODUCTION

Airborne Lidar is widely used to capture the geometry of the elements of high voltage overhead power lines. One of the advantages of this technology is the direct measurement of the geometry of wires. From this measurement, important properties like the sag of wires can be derived directly. Another strong point is, that the distance between structures of the power line to the proximate vegetation is directly measured (Figure 1). These properties are important to identify potential risks for safe operation.

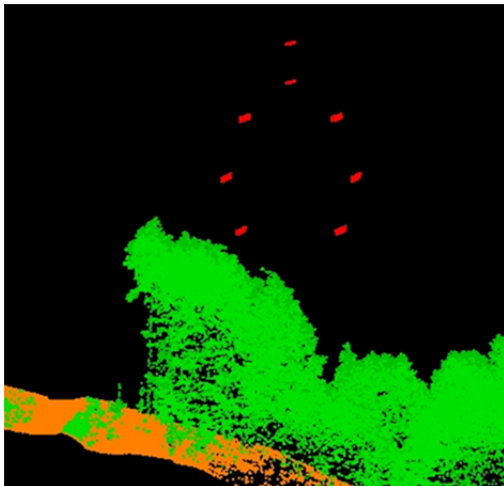


Figure 1: LiteMapper pointcloud of transmission wires over high vegetation (Milan Geoservice GmbH, Germany).

A disadvantage of a purely Lidar based assessment of power lines is the missing visual information about poles, wire suspensions and direct vicinity of the line. Even with extremely high point densities in the Lidar point cloud, the visual impression is indispensable in many cases.

For Lidar systems that are mainly used for terrain mapping, it became customary to capture aerial photographs together with the Lidar point cloud to improve the interpretability of Lidar measurements. For this application it is useful – and sufficient – to capture nadir images with a footprint width that is similar to the Lidar swath width. For power line mapping, this configuration is not optimal because the type and the status of the pole can hardly be seen (see Figure 2).

For that reason the *LiteMapper* Multi Sensor Platform is equipped with an airborne Lidar system and with nadir and oblique cameras. This system allows for simultaneous capturing of an extremely dense pointcloud together with high resolution photos of the poles from three perspectives (forward, backward and nadir). The system is mounted in an external helicopter pod. By this means the sensors can be mounted to a different helicopter of the same type within less than half a day. The flexible layout enables the operation with additional sensors like a thermal camera, a CIR camera or a video system with minimal modifications.



Figure 2: Power pole captured in nadir view.

## 2. SYSTEM COMPONENTS

The *LiteMapper* series of airborne Lidar mapping systems combine state of the art laser scanners with the *AEROcontrol* and other components of IGI's modular sensor systems.

### 2.1. Sensor Pod

For power line mapping and for other corridor mapping applications, where a helicopter is employed, the *LiteMapper* can be mounted in an external sensor pod. To allow an easy installation in different helicopters of the same kind, all components, except the user interface and the GNSS antenna, are mounted inside the pod. All sensor components that shall have the possibility for direct georeferencing with *AEROcontrol* data are mounted to a rigid carbon fiber plate. This sensor assembly plate is fixed to the mechanical structure of the pod with vibration dampers. The plate has two main holes for the sensor systems: one for the Lidar and one for the camera system.

The sensor pod shown in Figure 3 is certified for the use together with an Eurocopter AS350 helicopter.



Figure 3: *LiteMapper* Multi Sensor Platform operated on an AS 350 helicopter in the Russian Federation.

## 2.2. Flight Planning and Navigation

Navigation of power line survey flights with relatively low flying helicopters is mostly done without a dedicated survey flight navigation system. Nevertheless, it is useful to equip the Multi Sensor Platform with such a navigation system to keep it operational in situations where the pilot can't follow the line by sight. This can happen because the situation on the ground is too complex or the targeted power line can't be identified obviously. Furthermore, the installation of the navigation system expands the range of possible applications from the pure power line mapping to all other infrastructure corridor projects and to the high accuracy mapping of small areas, like industry facilities, mines and landfills.

Besides the provision of the input data for the navigation system, the mission planning software is used to estimate managing information like the duration of a mission, required storage space, possible flying speeds and altitudes. Figure 4 shows an *IGIplan* mission planning for a power line corridor mapping that was done for management purposes only (the footprints of the oblique cameras were blinded out for better clarity). The actual flight for this mission (see chapter 3. ) was conducted without using the *CCNS*.

Even though the pilot mostly follows the power lines by sight, it is important for a uniform and complete dataset that the planned altitude over ground is kept during the whole mission. To enable the pilot to control the real altitude over ground, this parameter is calculated in real time from Lidar range measurements. This value is displayed for the crew in the Lidar user interface and it is transferred to the *CCNS* and included to the navigation display.

The *LiteMapper* Multi Sensor Platform is equipped with the *CCNS* computer controlled navigation system and with *IGIplan* for mission planning.



Figure 4: Left side: *CCNS5* Navigation System. Right side: Mission planning with *IGIplan* (the oblique footprints are blinded out for a better clarity).

### 2.3. AEROcontrol GNSS/IMU System

The *AEROcontrol* GNSS/IMU system provides the precise position and orientation for georeferencing of the Lidar pointcloud as well as of the nadir and oblique photos. The *AEROcontrol* SMU (Sensor Management Unit) can collect feedback signals of multiple sensors. For that reason, additional equipment like the sensors described in chapter 2.6. can be time-tagged and georeferenced as well. For all *LiteMapper* systems the *AEROcontrol-IIe* with 256 or 400 Hz data rate is used.



Figure 5: *AEROcontrol-IIe*

### 2.4. LIDAR

In the Multi Sensor Platform which is optimized for Power Line Mapping, IGI integrates a high end laser scanner. At a data rate of 400 kHz this scanner provides an effective measurement rate of 266,000 measurements per second with an unlimited number of returns per laser measurement.

### 2.5. Camera System

The camera system is a combination of three *DigiCAM* aerial cameras mounted under different pitch angles. All cameras are mounted with the long side of the image across flight direction.

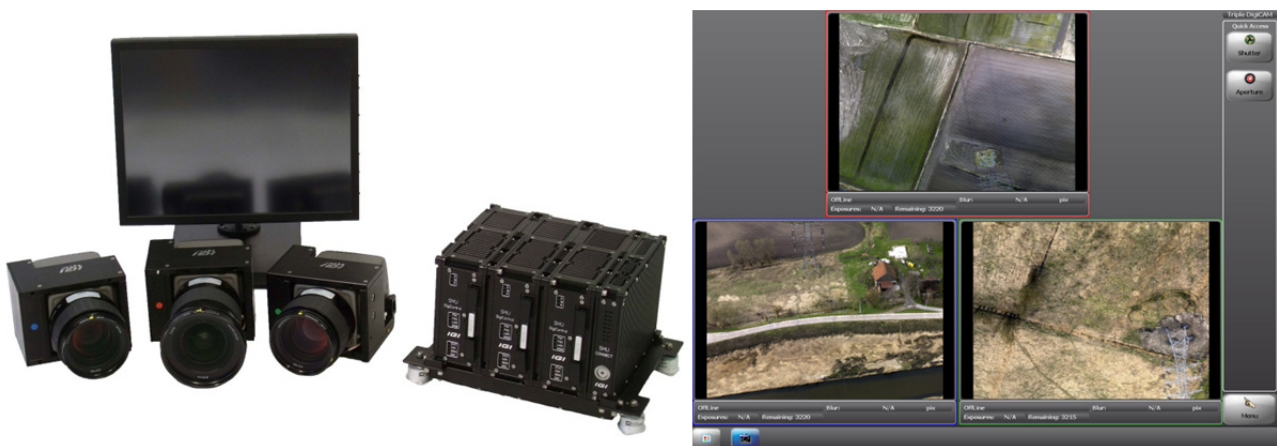


Figure 6: *DigiCAMs* with 50mm and 100mm lenses together with the *DigiControl* SMUs (Sensor Management Units) and the user interface.

The two oblique cameras are mounted with  $+45^\circ$  pitch and  $-45^\circ$ , respectively. They operate lenses with 100mm focal length. The nadir camera operates a 50mm lens. This combination creates the footprint given in Figure 7.

As a difference to conventional terrain mapping, where only the footprint of the photos on the ground is relevant, the correct coverage of large vertical features has to be realized. Figure 8 shows the FOV (Field of View) of the three cameras seen from a position perpendicular to the power line.

In this example, the flying altitude is 150m and the height of the pole symbols is 50m. This example illustrates the importance of information about the actual flying height above ground as explained in Chapter 2.2. In the given scenario, the use of an altitude above an existing DTM (Digital Terrain Model) could lead to unacceptable errors in the flying height and thus in missing information in the dataset.

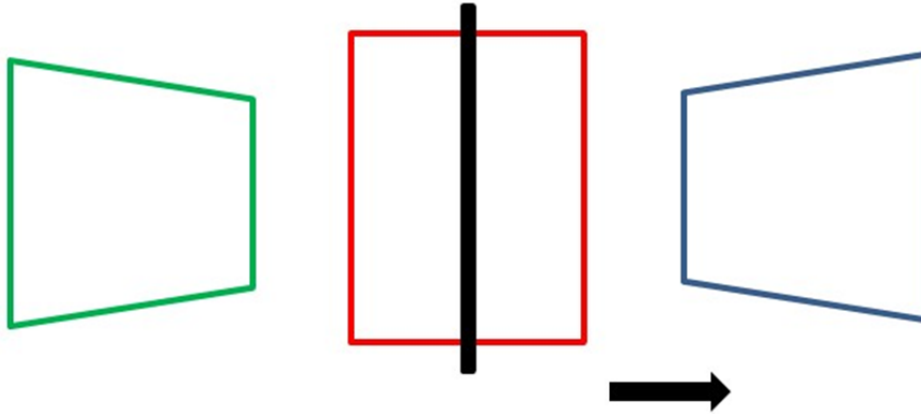


Figure 7: Footprint of the camera system. The bar in the middle indicates the Lidar swath width.

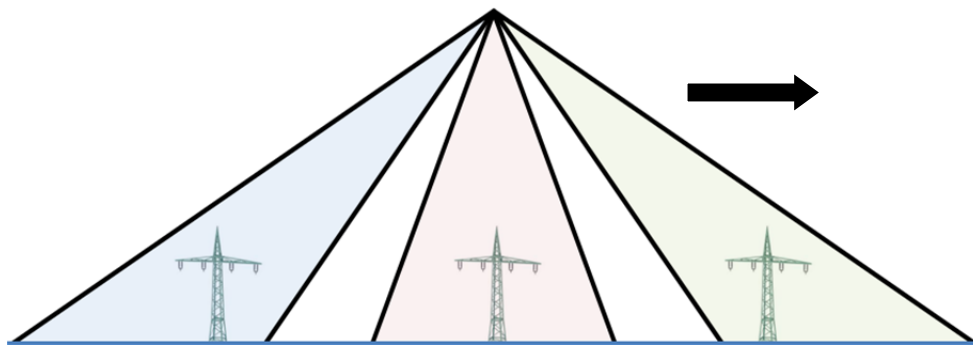


Figure 8: Vertical coverage of the cameras. The height of the pole symbols is three times smaller than the flying altitude.

The installed *DigiCAMs* are operating at a minimum repetition time of 1.6sec. Consequentially there will be at least one photo in which the full extent of the pole is covered (for a helicopter speed of 50kn or less and 150m flying altitude).

## 2.6. Auxiliary Sensors

Because of the modular architecture of the *LiteMapper*, the system can be extended with additional sensors like a digital video system or a thermal infrared camera.

If thermal infrared information should be collected the *DigiTHERM* camera can be added. Since the *DigiTHERM* uses the same Sensor Management Unit (SMU) as the *DigiCAMs*, it would even be possible to replace one digital camera by a thermal camera without any further changes in the system layout. In this case, the graphical user interface would adapt to the different sensor layout and no additional user interface is needed. Other possibilities are the integration of a video system or modification of one of the *DigiCAMs* to CIR mode.

### 3. APPLICATION EXAMPLE

In 2010 and 2011 the company MGGP Aero, Tarnów, Poland is capturing Lidar data and images of about 8800 km of power lines for the operator of the high power line transmission system in Poland. MGGP Aero uses one of their two IGI *LiteMapper* systems to fulfill this task and to deliver the following products:

- the Lidar point cloud (classified in ground, vegetation, buildings, roads, power poles and power lines)
- digitized power lines
- shape files with the pole positions
- oblique images of the poles (forward)
- oblique images of the poles (backward)
- an orthophoto mosaic of an 80m wide corridor around the line.

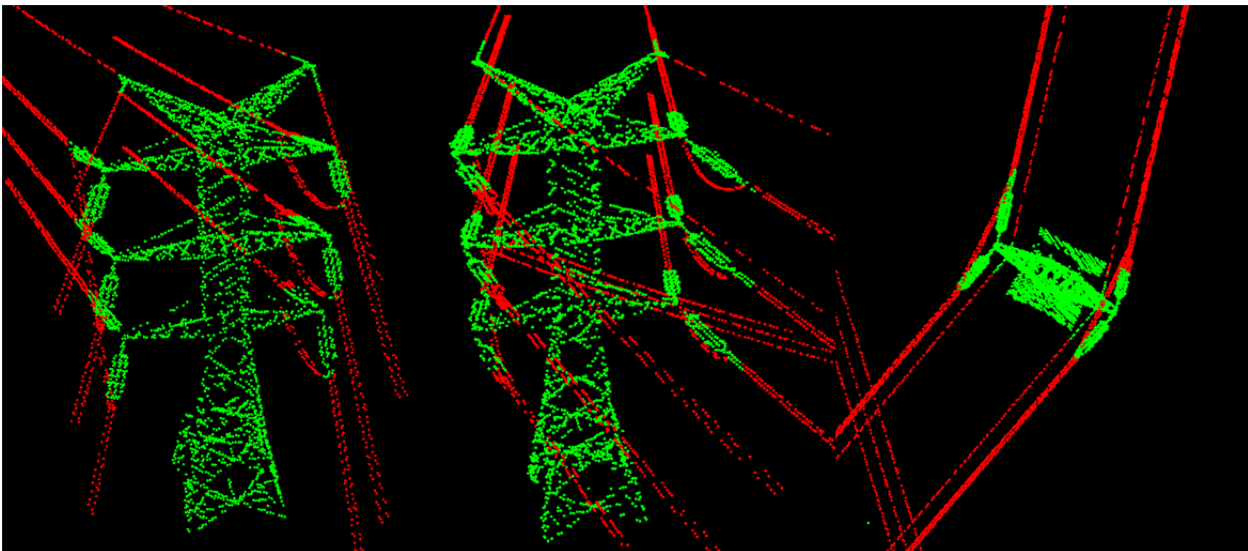


Figure 9: Point cloud and photo of the same pole for the forward, backward and nadir view.

Most of the project is flown at an altitude of about 150m. This altitude allows for a safe flying operation and it results in an adequate Lidar swath width of 173m and nadir image width of 130m. The images in the three directions are captured simultaneously with a distance of 50m in between two image positions. The nadir images are processed to an orthophoto mosaic. For the orientation of the images, the *AEROcontrol* information is used (Direct Georeferencing). Processing of the data has to have high grade of automation, because all results have to be delivered within 20 days after data acquisition.

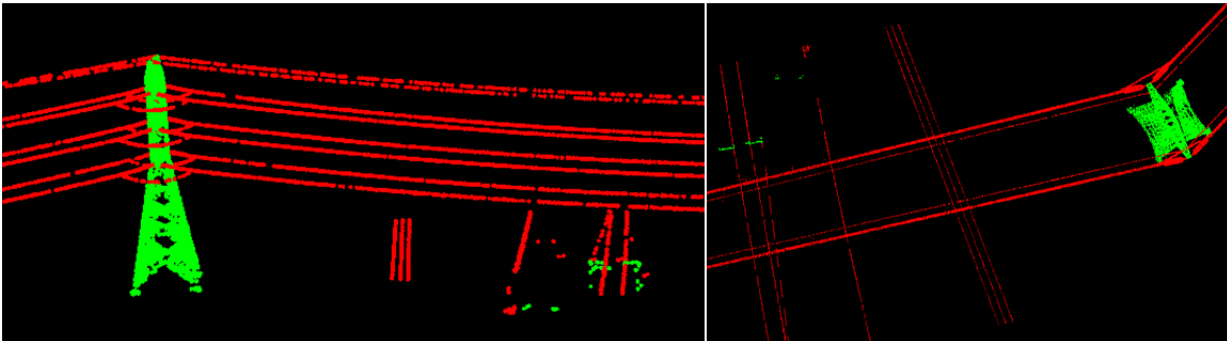


Figure 10: Detail in oblique and nadir view: crossing of high voltage line with lower voltage power lines.



Figure 11: Detail views. Left side: Maintenance at work. Right side: Wire suspension with lower voltage power line pole in the background.

Until summer 2011, about two thirds of the project has been finished successfully. The last part of the project is currently being flown and processed.

#### 4. CONCLUSION

The *LiteMapper* Multi Sensor Platform in the described configuration is a specialized tool for power line mapping from helicopters. It combines the power of conventional Lidar mapping with the advantages of high resolution oblique images. The certified integration of the equipment into an external helicopter pod enables the installation of the system within half a day.

The given application example illustrates the high efficiency of the survey platform. As much as nearly 9000km of power line, resulting in about half a million images is captured successfully with a single system within two flying seasons.

## **5. ACKNOWLEDGEMENTS**

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