# AIRBORNE LASER SCANNING FOR THE PURPOSE OF HYDRODYNAMIC MODELLING OF WIDAWA RIVER VALLEY *

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**ABSTRACT**

**Airborne Laser Scanning (ALS) is a new technology for capturing data for a detailed Digital Terrain Model (DTM) determination, especially in shrubbed and wooded areas. This measurement technique enables 3D-reconstruction of the terrain and its topography with the resolution of point per m$^2$. ALS was applied for DTM generation of Widawa river valley. This DTM will facilitate hydrodynamic modelling. The measurements were taken by the panel of researchers from Agricultural University of Wrocław in co-operation with the University of Stuttgart. In the project, the prototype of continuous wave laser scanner ScaLARS was used.**

## 1. INTRODUCTION

**Digital terrain models (DTMs) are often a standard method of surface description applied in various engineering and modelling issues, for instance in defining hydraulic features of a river valley or flood wave flow simulation. DTMs built for the need of hydrodynamic modelling encompassing river valleys and their surroundings should characterize great accuracy and rigorousness in land formation projection. It especially refers to such elements of landscape formation as slopes and river banks. Recording the elements of this type with insufficient rigorousness or geometric precision, or what is worse, their omission in DTM leads to falsifying the results of hydrodynamic modelling, which in the situation of flood danger may cause catastrophic effects.**

**Generation of DTM that owns the attributes mentioned above is almost impossible when traditional methods for data acquisition, specially in wooded areas, are used. However, airborne laser scanning (ALS) makes it possible. Great density of survey points, which estimates a few points per m$^2$ and the value of penetration coefficient which varies from 30% to 70%, connected with high positional accuracy enable generation of detailed and precise DTMs and Digital Surface Models (DSMs).**
**Airborne Laser scanning was performed for 20 km-estuary section of Widawa river. ScaLARS scanner prototype built at University of Stuttgart was applied for the**

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**scanning process. Scanning was taken to build accurate DTM (DSM) as well as to carry out hydrodynamic modeling. This paper presents general information on the technology and preliminary results of the project realization. The scope and possibilities of ALS products application in hydrodynamic modelling were pointed.**

## 2. AIRBORNE LASER SCANNING – SCALARS SYSTEM

**Airborne laser scanning is data capturing technology, which integrates three independent measurement techniques:**

- **GPS (Global Navigation System) for position determination,**
- **INS (Inertial Navigation System), also called IMU (Inertial Measurement Unit) used for determination of angles which orientates survey platform in the space,**
- **LRF (Laser RangeFinder) for laser measurement of distance between points and the earth.**

**The set is completed by a survey platform, which carries the scanner. In majority of cases, the platform is simply an airplane. For scanning long and narrow objects such as electric cables, a helicopter may be also used. It is common knowledge what ALS is and how it works. Particular laser scanning components' co-operation is presented in the form of draft in Fig. 1. Characteristic feature of ScaLARS is the way of area sampling. The laser samples the area not in vertically to flight direction but along ovals which resembles ellipses.**

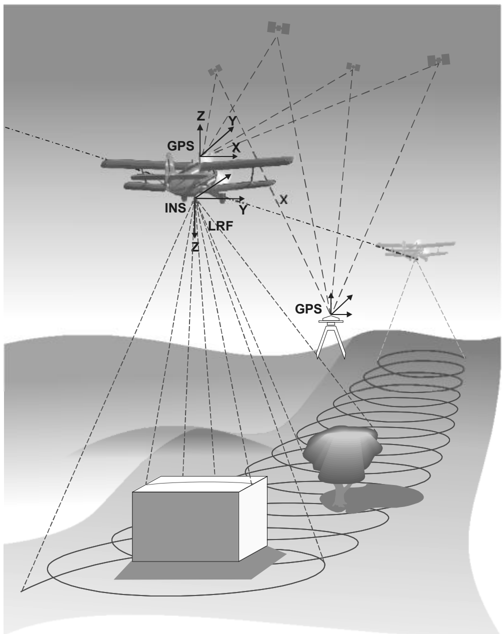


**Fig. 1. Airborne Laser Scanning (ALS) components**

**Fig. 2 depicts ScaLARS scanner prototype. This device is unlike the other scanners because it uses continuous wave and a beam is diverged by means of rotating mirror. Connection of mirror rotation and plane movement results in survey points distribution along the ellipses, which moves in the scanned area.**

**ScaLARS registers signal's run and return time, on the strength of which distance to the earth or to any other object reflecting signals is determined. The system also registers beam reflection intensity. Basic scanner's parameters are given in Table 1.**

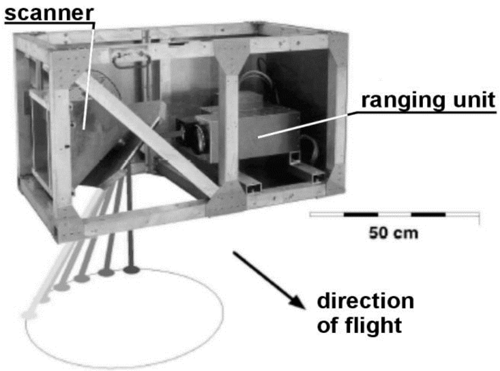


**Fig. 2. ScaLARS System**

**Table 1. Technical specification of ScaLARS**

| Parameter | Value |
|---|---|
| Laser source | CW laser diode InGa(Al)As |
| Detector | SI avalanche Photodiode |
| Radiation power | 0.8 W |
| Laser wavelength | 810 nm (IR) |
| Modulation frequency | 10 MHz, 1 MHz |
| Max. slant range | ~ 750 m |
| RMS (95%) | 0.03 m .. 0.16 m |
| Beam divergence | 1 mrad |
| Sample rate | 7,69 kHz |
| Rotation rate of mirror | 20 Hz |
| Color depth | 13 bit |
| FOV | 28° or 40° |

**For GPS and INS signals registration Applanix system is used, which is Position and Orientation System for Airborne Vehicles (*POS/AV*). The Applanix is used to provide real-time navigation for the purpose of flight guidance and post-processed orientation data for the purpose of geocoding of airborne sensor data. As for main components, Applanix *POS/AV 510* comprises:**

- **an Inertial Measurement Unit (*IMU*),**
- **a NovAtel OEM *GPS* receiver,**
- **an Applanix Positioning and Orientation Computer System *PCS*,**
- **an internal mass storage drive,**

- **several interface boards for communication,**
- **a Controller Notebook.**

***IMU* is a gyroscopic device, which allows determining three orientation angles: roll (ω), pitch (φ) and heading (κ). In Differential Positioning on post-processed mode possible to obtained accuracy are (all values RMS): position 0.05 – 0.30 m, velocity 0.005 m/s, roll and pitch angle 0.005 deg, heading 0.008 deg and max. data rate 200Hz. When the scanner is placed in the airplane and GPS aerial antenna is mounted, displacement vector from user origin (sensor perspective center) to GPS antenna phase center should be determined.**

## 3. PROJECT WIDAWA

**As a part of this research project, in November 2005, airborne laser scanning of Widawa river valley fragment was performed. The study area comprised 20 km-estuary segment of Widawa river valley. Flight mission was carried out in accordance with the following project parameters:**

| | |
|---|---|
| - **Speed flight:** | **150km/h** |
| - **Flying height:** | **550m** |
| - **Swath width:** | **280m** |
| - **Distance between scanning flight lines:** | **190m** |
| - **Width of study area:** | **2km** |
| - **Length of study area:** | **20km** |
| - **Number of strips:** | **11** |

**ScaLARS system was mounted on the board of AN-2 airplane. In order to find scanner position and orientation in the space, Applanix system was used, while for GPS signal registration on two ground reference stations Trimble 4700 and Ashtech receivers were applied. Fig. 3 depicts applied components. Before the flight, tested area for calibration were designated and measured. Same part of a flat runway was used as a calibration area. Navigation during flight was carried out with application of GPS technique using signal from Applanix system.**

**During the measurements 150mln of points were captured which gives on average 3pts/$m^2$. Distances between adjacent points in particular scans take about 0.6m.**

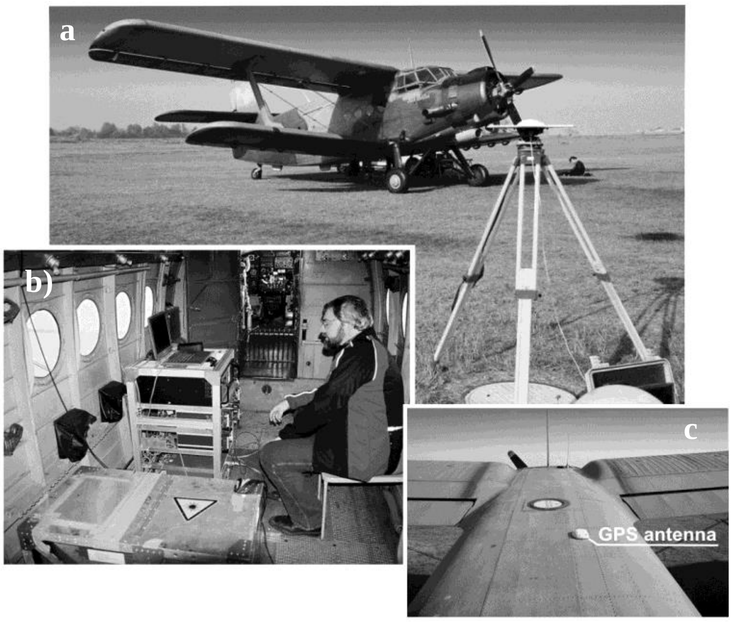


**Fig. 3. a) AN-2 airplane and one of GPS reference station, b) scanner and control unit inside of airplane, c) airborne GPS antenna**

## 4. DATA PROCESSING AND PRODUCTS

**Procedure describing data acquisition and processing from airborne laser scanning is depicted in Fig. 4. The crucial part of data processing is calibration and geocoding of data gained in laser scanning. In the project a new user-friendly LASCAL (LASer CALibration) software was used (Schiele et al., 2005). The system calibration parameters values are estimated using the Gauss-Markoff model. The calibration is realized in software semi-automatic. The results of calibration are shown in Table 2. At the stage of calibration, scanner's position and orientation in the plane were determined as well as absolute errors (mean value) with respect to GPS calibration area. These errors along and across flight direction are 0.3 m and vertical 0.1 m. The outcome of laser scanning data calibration and geocoding are survey points coordinates {B,L,h} in WGS84 system and reflection intensity. These coordinates have to be transformed to the obligatory coordinates system (PUG 1992 and Kronsztadt 86).**

**The final stage in data processing is DTM and DSM generation. After appropriate survey data processing and false reflections elimination, a set of points which were reflections from the ground, buildings and vegetation was obtained. It enabled DSM interpolation, the fragment of which is presented in Fig. 5a). Applying appropriate algorithms of semi-automatic filtration (Borkowski, 2004), points which were not reflections from the ground were eliminated. After that, appropriate DTM was built, the fragment of which is presented in Fig. 5b). Difference between DSM and DTM gives the model which describes objects height. The extract of generated model is presented in Fig. 5c). In order to visualize and improve the appearance of survey area, orthophoto was put on DSM. This process is presented in Fig. 5d). DTM, DSM, DSM-DTM difference model and orthophoto were used in water flow resistance factor estimation.**

**On the basis of geometrical information, river banks will be modelled. For these modelling methods proposes in papers (Borkowski, 2004; Borkowski and Keller, 2005) will be applied.**

**Apart from geometrical information, which are points coordinates, laser scanning data also comprises information on the laser beam reflection intensity. This value depends on surface and may constitute one of the features in automatic classification of pictures and resistance coefficients estimation. Fig. 6 exemplifies reflection intensity image. On the strength of intensity, we may distinguish wooded areas or indicate Widawa river and its banks run. In the top right corner, diverse structures of cultivation on arable lands are presented. Other objects such as buildings, roads and rail embankments are also vivid in the intensity picture.**

**Fig. 7 shows typical vertical cross section of laser scanning data in wooded areas. In this picture, we may notice the line of reflections from surface in the bottom part and over it, the line of reflections from the trees canopy. A distinct break is seen between those two lines. Separate points appear in the break. Such a profile makes it possible to determine the average height of the first level of branches over the ground. The information also supports resistant coefficients search. What is more, vertical profile also shows wood density change. This change may be found by analyzing the number of laser reflections (number of points) on the particular levels.**

**Finally, the accuracy of acquired data must be investigated. Height determination accuracy is of great importance. This accuracy was determined by comparing the heights of characteristic points, for example ground parts of provisions of services, with appropriate laser scanning points. Heights of characteristic points are given on basic maps in a scale 1: 500 with the accuracy of 1cm Therefore, they may be treated as faultless. Laser scanning standard error calculated on the basis of several points from different areas estimated $\pm$0.20m. This accuracy is sufficient for the purpose of hydrodynamic modelling.**

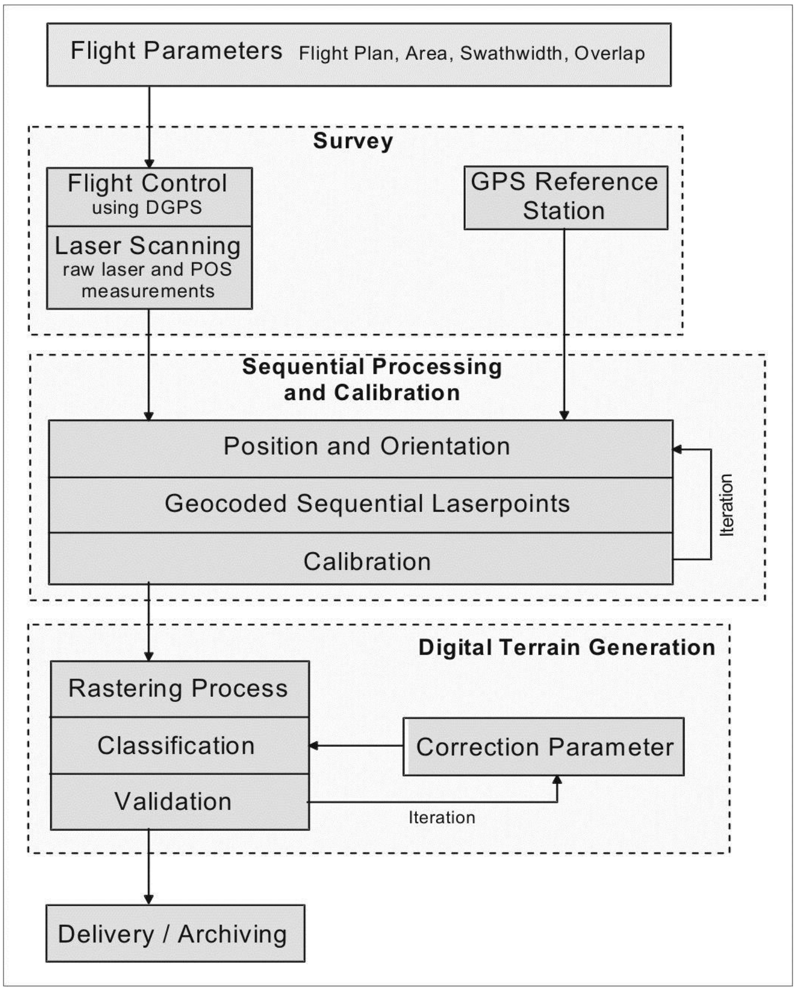


**Fig. 4. Operational processing chain (Thiel and Wehr, 2001)**

**Table 2. The calibration parameters**

| | parameter | values | Standard dev. | Remark |
|---|---|---|---|---|
| scanner | wobble angle $\gamma_M$ | 6.895 deg | ± 0.007 deg | |
| bore-sight misalignment angels | roll $\delta\omega$ | + 0.636 deg | ± 0.010 deg | |
| | pitch $\delta\varphi$ | - 0.476 deg | ± 0.010 deg | |
| | heading $\delta\kappa$ | - 0.466 deg | ± 0.056 deg | |
| ranging | slant range offset *Add* | + 0.143 m | ± 0.048 m | |
| FOV | across flight direction | 27.580 deg | -- | calc. with $\gamma_M$ |
| | along flight direction | 19.306 deg | -- | calc. with $\gamma_M$ |

| | along flight direction (local frame) | across flight direction (local frame) | vertical |
|---|---|---|---|
| Estimated residuals with respect to control areas | ± 0.6 m | ± 0.4 m | ± 0.15 m |
| Absolute error (mean value) with respect to GPS control area | 0.3 m | 0.3 m | 0.1 m |

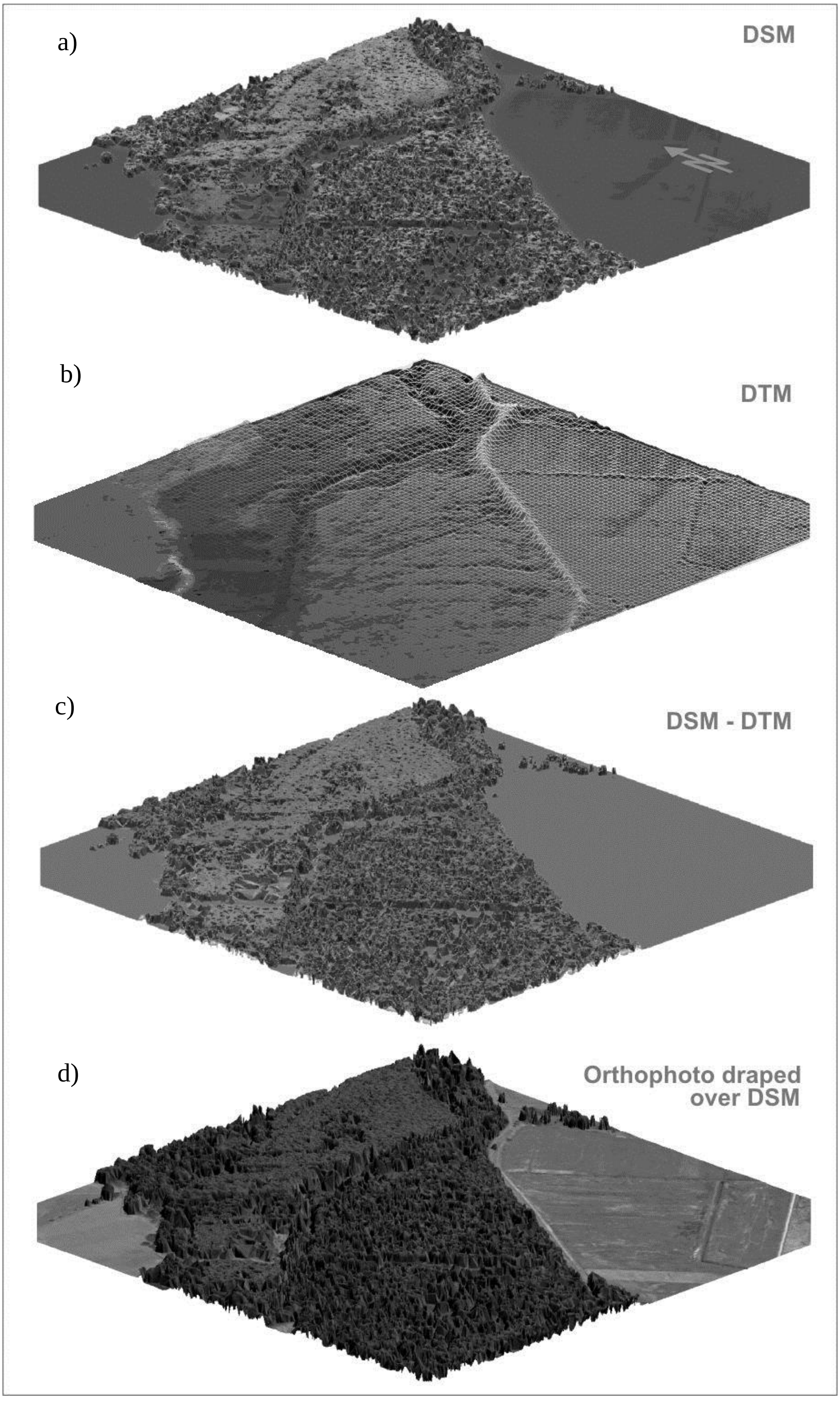


**Fig. 5. Important products for hydrodynamic modelling**

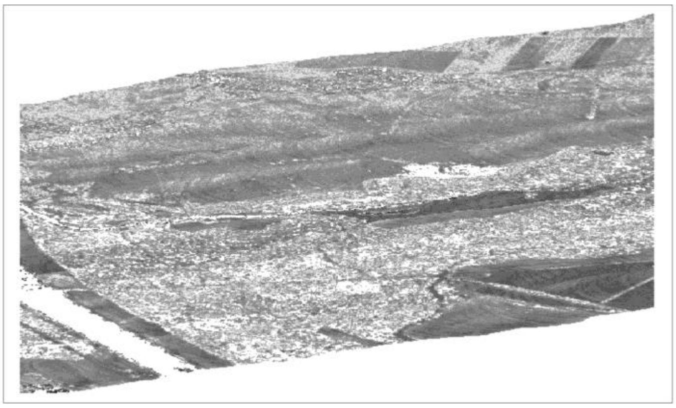

**Fig. 6. Reflection intensity image**

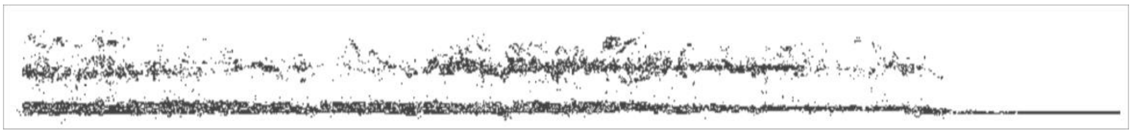

**Fig. 7. Cross-section: point cloud over afforested area**

## 5. CONCLUSIONS

**Airborne laser scanning is the rapid and accurate method of detailed geometric information on scanned surface capturing. This method is uncompetitive in remote wooded areas. In the presented project *Widawa* initial vertical accuracy of ca ±0.2 m and density of points ranging from 2 to 3 pts/m$^2$ were gained. In the context of hydrodynamic modelling, this method seems very attractive because:**

- **differential model (DSM-DTM) is applied in resistant factor estimation,**
- **reflection intensity image is also applied in resistant factor estimation,**
- **laser reflection distribution in vertical cross-sections may be used for wood layers estimation**
- **DTM is used for flood wave flow modelling.**

**Taking into consideration poor reflections capacities of very humid areas, it is advantageous to perform river valleys laser scanning in the periods when water level is low.**

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