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# High Resolution Laserscanning, not only for 3D-City Models

UWE LOHR, Ravensburg

**ABSTRACT**

The TopoSys laserscanner system is designed to produce digital elevation models (DEMs) of the environment at a typical accuracy of 0.5 m in x, y and 0.15 m in z. The exceptional measurement frequency of 83 000 measurements per second results in about five measurements per m² on ground, when surveying from an aeroplane – from a helicopter the measurement density is even higher. This measurement density and the regular scan pattern (parallel lines) form the basis for high quality DEMs.
TopoSys DEMs meet the stringent requirements, which are common in such applications as urban planning, water resources management, shoreline monitoring, and corridor mapping. The paper gives an overview on the system capabilities and illustrates the DEM quality with help of some examples from project.

## 1. INTRODUCTION

In the recent years an increasing demand on high-precision digital elevation models (DEMs) has to be noted - high-precision in this sense means that the accuracy of the DEMs is better than 1 m in x, y and about 0.2 m in z. Many of those applications not only request for high precision, but also demand a short delivery time. Typical applications are monitoring of coastal erosions, simulation of floods in river basins in order to determine engineering works, and simulation of antennae sites or line-of-sight calculations for mobile communication networks.
For some years laserscanner have shown their ability to meet above requirements and meanwhile are an operational tool for DEM generation. The TopoSys laserscanner system integrated into a fixed wing aircraft has delivered thousands of km² of high resolution DEM for such applications. Recently the TopoSys system has been mounted into a helicopter to start a new application: *Integrated Helicopter Corridor Mapping* IHCM.

## 2. DESCRIPTION OF THE SYSTEM

During a laser scanner survey with the TopoSys system, all sensor data (see also Figure 1) are recorded digitally. LINS, GPS, laser data and RGB linescanner data are stored on exchangeable PC harddisks, while video scenes are stored on a digital tape. The operator onboard the airborne platform only monitors the performance of the system, in case of the laser data with help of a real-time waterfall display.
GPS data is registered with help of a *Novatel* Millennium L1/L2 receiver at a data rate of 1 Hz, while the high precision LINS (Laser Inertial Navigation System) collects position and attitude data at a data rate of 64 Hz. After flight path restitution and merging of dGPS and LINS measurements, position and attitude data are available at 64 Hz. This means that at a cruising speed of a fixed wing aeroplane of about 70 m/sec the system's orientation is known each meter.
The totally eye-safe laser sensor operates at 1.54 µm, at pulse rate of about 83 kHz and a scan frequency of 630 Hz. The scan angle is fixed to +/- 7° in order to minimise shading effects especially at the borders of the swath. From a survey altitude of 1000 m the swath width on ground is about 250 m, the average measurement density is four to five measurements per m². Swath width – and measurement density – can be adapted to the project's needs by choosing the appropriate survey altitude.

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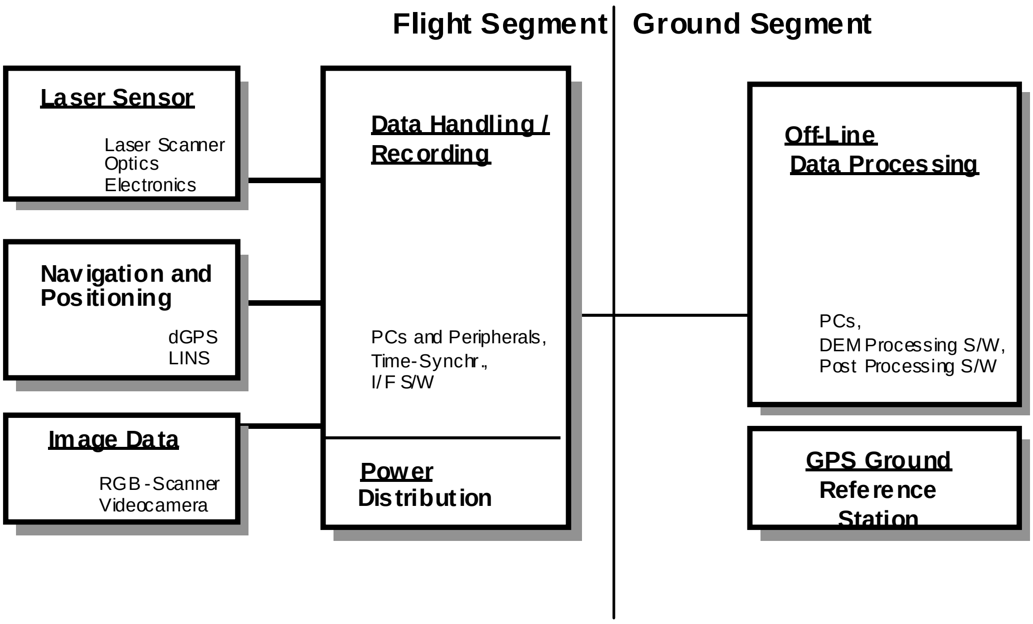


Figure 1: TopoSys system components.

The down-looking video camera, which has been part of the TopoSys sensor package in former days, recently has been replaced by a four-channel (R, G, B, IR) linescanner. This linescanner provides a pixel size of about 0.4 m from a survey altitude of 1000 m and allows generating “colour ortho-photos“ of the survey area. The line-scanner data are expected to support the segmentation of DEM data, too.
The application *Integrated Helicopter Corridor Mapping (IHCM)* is done from a helicopter like a Bell Jetranger 206. In case of IHCM, a 45° forward looking digital video camera completes the sensor package and records a video sequence of the surveyed tracks (see also Figure 2). Typically survey altitudes in IHCM applications are between 200 m and 600 m above ground. Due to the relatively low survey altitude and cruising speed of a helicopter, the measurement density on ground is typically more than 20 measurements per m².

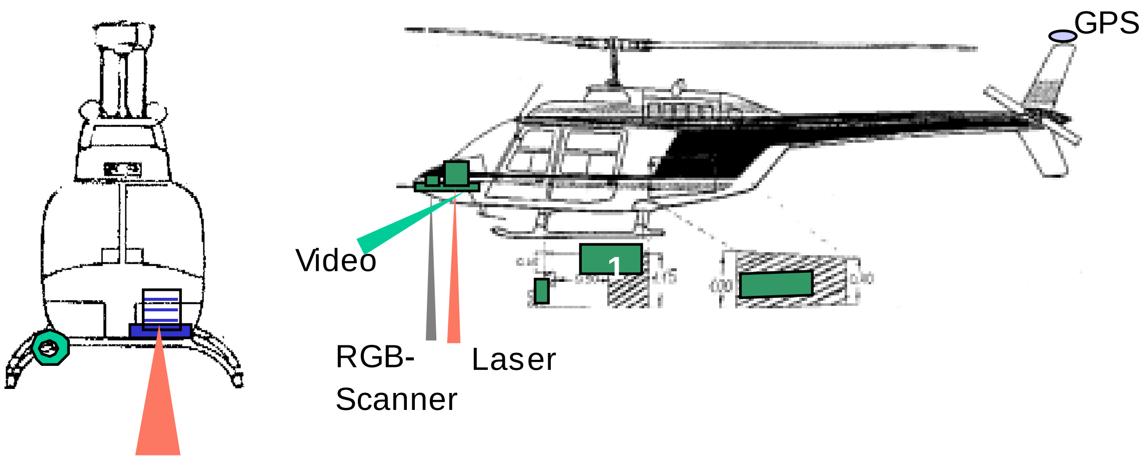


Figure 2: IHCM sensor package.

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The off-line data processing is done by high-end PCs. Key software packages are a package for flight path restitution and the TopoSys software for DEM generation and post-processing; IHCM post-processing is made by a special package in ARC-INFO environment.
As consequence of the high measurement density, full resolution DEM data are rarely delivered to the client; the standard product is a 16 bit raster DEM in some regular grid (0.2 m, 0.5 m 1 m ,...). Survey altitude (and by this measurement density) and raster width are chosen in such a way, that always several elevation measurements are available to allow statistical and plausibility analyses when calculating a single DEM representative of a grid cell.
The presently operational TopoSys I system will be replaced by the TopoSys II series in late autumn 1999. Performance parameters of TopoSys II are given in the following table.

| | |
|---|---|
| sensor type | pulse modulated laser radar |
| Range | □ 1 600 m |
| Scanning principle | fibre optic line scanner |
| Transmitter | solid state at 1.5 µm |
| Measurement principle | run-time measurement, intensity, first + last pulse |
| laser pulse rate | 83'000 Hz |
| scan frequency | 630 Hz |
| field of view | +/- 7° |
| Number of pixels per scan | 127 |
| swath width (at 1000 m flight height) | 250 m |
| resolution of a distance measurement | < 0.03 m |
| height accuracy of TopoSys DEMs | < 0.15 m |
| laserscanner classification | Class 1 by EN 60825 (eye-safe) |

Table 1: Performance Parameters of TopoSys II.

## 3. DEM EXAMPLES FROM SURVEYS

Some applications in which TopoSys DEM are used as basic data are urban and environmental planning, simulations of floods and powerline surveys. The following examples of projects have been chosen to illustrate the quality and capability of laserscanner DEMs.

### 3.1. 3D City Models

The vicinity of the city of Karlsruhe was surveyed 1998. Figure 3 shows a 3-D presentation of the DEM raw data, which is overlaid by a scanned ortho photo. The DEM still includes vegetation and buildings, however, these objects can be removed by semi-automatic filtering to receive the classical digital terrain model DTM.
Except from mobile communication applications, such models are an excellent database for a variety of urban planning purposes, for simulation of floods, simulation of distribution of noise and pollution.

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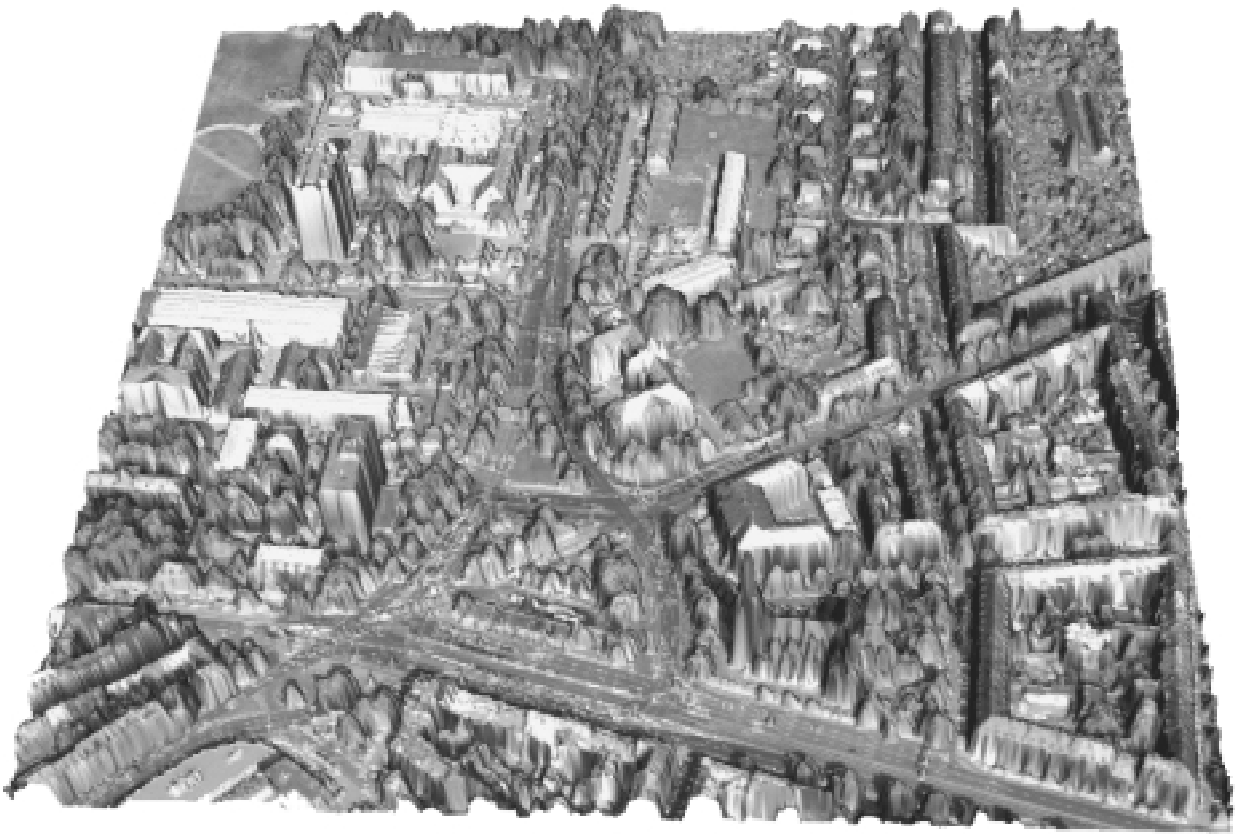

Figure 3: 3D-city model of Karlsruhe, Germany.

(Courtesy: Ross Whitaker, Dept. of Elec. Eng., Univ. of Tennessee, Knoxville)

Figure 4: 3D-city model of Karlsruhe, Germany.

### 3.2. Integrated Helicopter Corridor Mapping

Energy providers need detailed information on the location and the present technical status of their facilities network. Energy lines often follow rough terrain, which is difficult to access from ground; nevertheless, permanent monitoring is mandatory and acquisition of accurate and latest data necessary. *Integrated Helicopter Corridor Mapping* (*IHCM)* is new application developed by TopoSys GmbH, ESRI Germany and Rotorflug, Germany to survey medium and high voltage powerlines. IHCM integrates airborne laserscanner data into a *Powerline GIS- and Management Information System*. Depending on a client's requirements a spectrum of services is available, from the delivery of the purely data to turnkey systems including maintenance and training of staff.

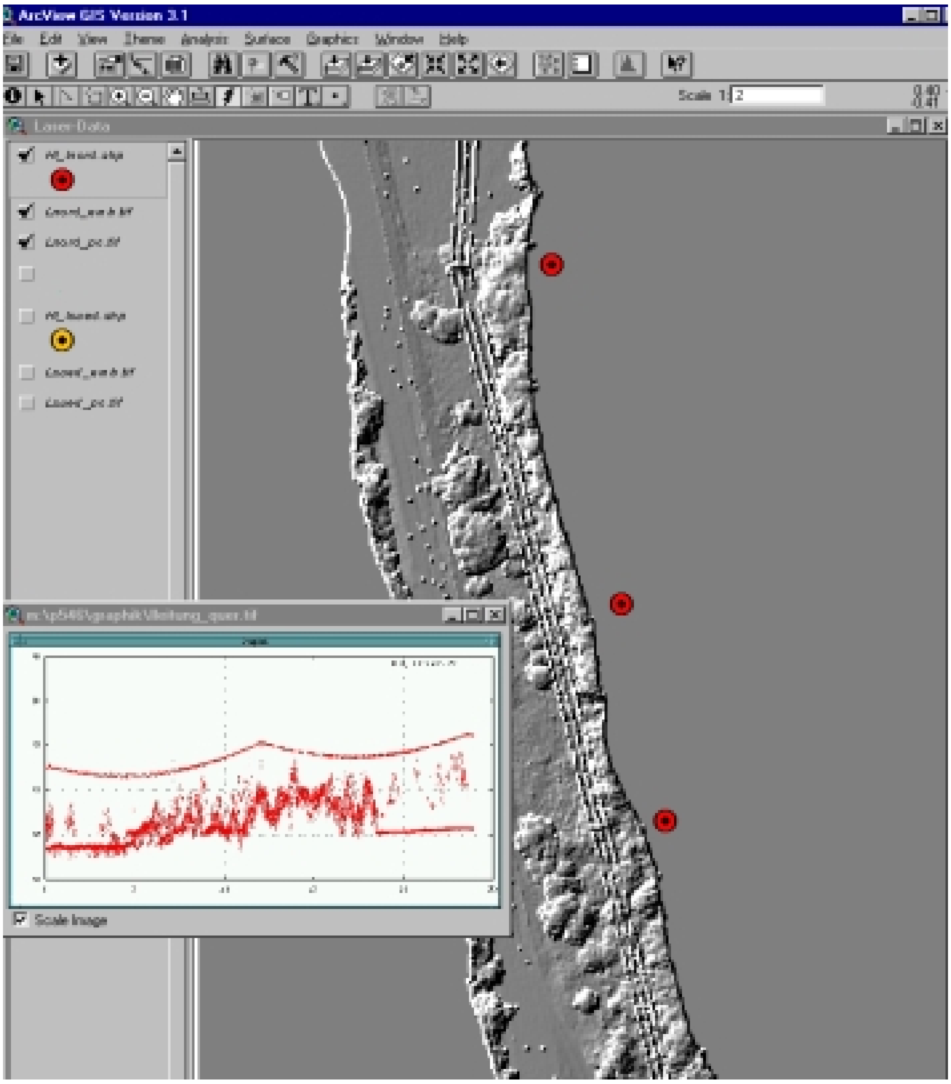


Figure 5: DEM of a medium voltage powerline.

Figure 5 shows the DEM of a medium voltage powerline as relief presentation. Cross sections and trans sections may be produced to visualize the distance of vegetation to powerline. However, in the IHCM system only line parameters are extracted interactively, vegetation/line distance maps and vegetation management plans are created mainly automatically from DEM and image data.

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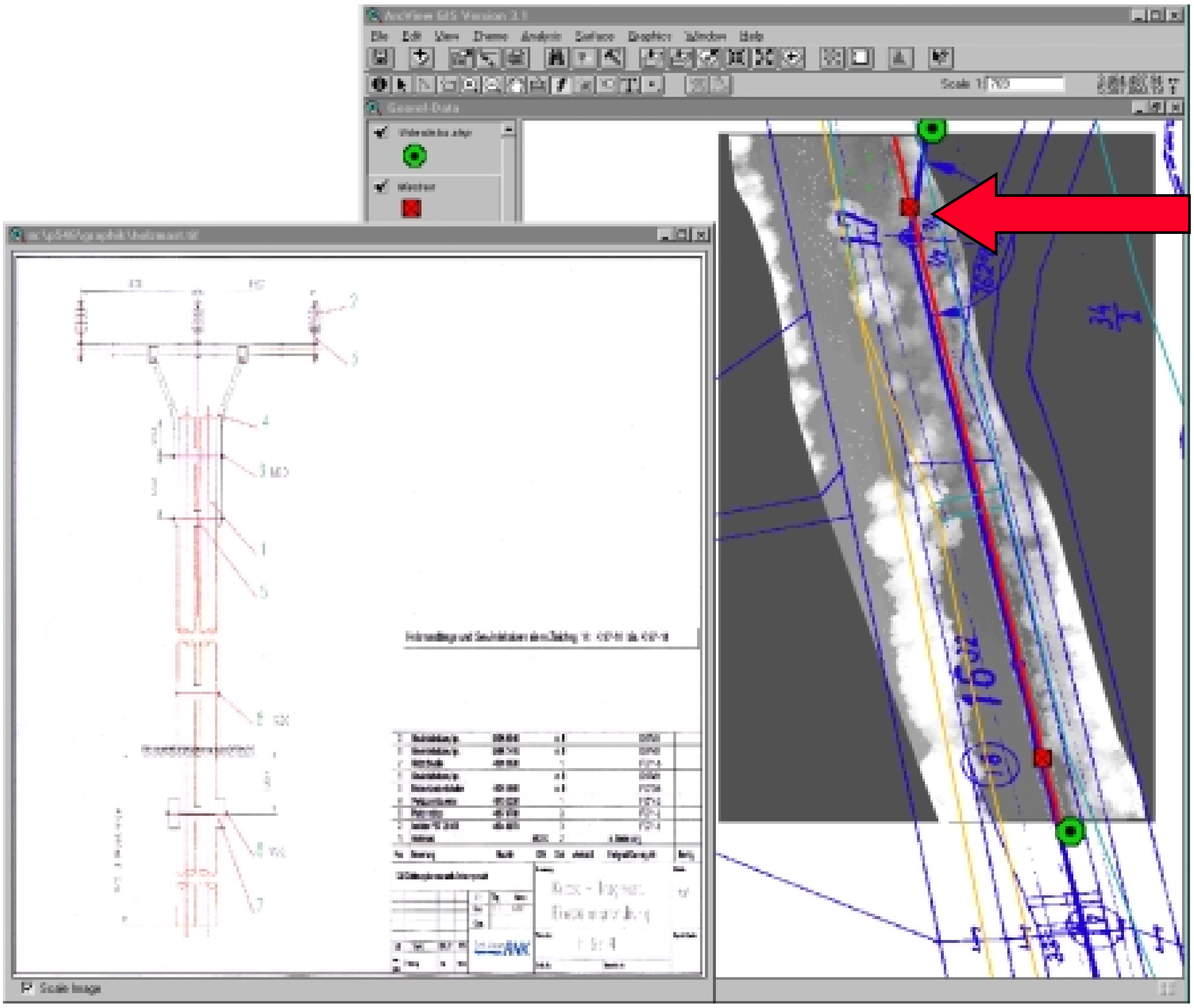

Figure 6: Laserdata integrated in a GIS environment.

The example in Figure 6 shows laserscanner data as one source of information in a *Powerline and Vegetation Management System*. Hotlinks allow such cross-references as links to (existing) databank information on CAD drawings of poles or to the video scenes recorded by the 45° forward looking camera.

Another output of the system is a *Vegetation Management and Maintenance Plan* which provides medium term priorities for clear-cutting.