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The TopoSys Laser Scanner-System

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ABSTRACT

The paper describes the TopoSys Laser Scanner system, which has been developed to produce high-precision digital elevation models of the environment on an operational basis. Architecture and performance parameters of the system are outlined and an reference DEM is given to illustrate the capability of the presented system.

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 final resolution of the DEMs is in each of the three components x,y,z < 0.5m. Many of that applications request not only high-precision, but also a short delivery time for DEMs of larger areas. Typically such kind of DEMs of the environment are needed for

- telecommunication (to optimise antenna sites with help of computer simulations),
- shoreline control,
- monitoring of pit depressions and open pit monitoring.

Laser Scanners are well known for their ability to measure distances with high accuracy. Due to their measurement principle, Laser Scanners support a complete digital processing and are therefore the appropriate choice for an automatic generation procedure of DEMs. A Laser Scanner to be used as sensor system from an aeroplane, however, must beneath others provide such features as

- cruising altitude at least 1000 m,
- eye-safety.

The TopoSys System, which is based on a Laser Scanner Sensor, has been developed to meet all these briefly summarised requirements and is designed to provide high precision DEMs on an operational basis.

2. TOPOSYS SYSTEM ARCHITECTURE

The TopoSys system can be divided into an flight and ground segment (see figure 1).
The primary task of the flight segment (aircraft system) is to acquire and store high-precision data for post-processing. The secondary task of the system is to provide medium-precision on-line data for navigation and guidance during the TopoSys survey flight. An important pre-mission element is, of course, to produce a digital flight plan which determines the trajectory to be flown.
During a survey flight the tasks of the ground segment are to collect GPS data for the post-mission differential GPS (dGPS) evaluation and to deliver, if necessary, data for high-precision on-line guidance. After data acquisition the off-line data processing system in the laboratory allows for an automatic generation of the high-precision DEM of the survey area.

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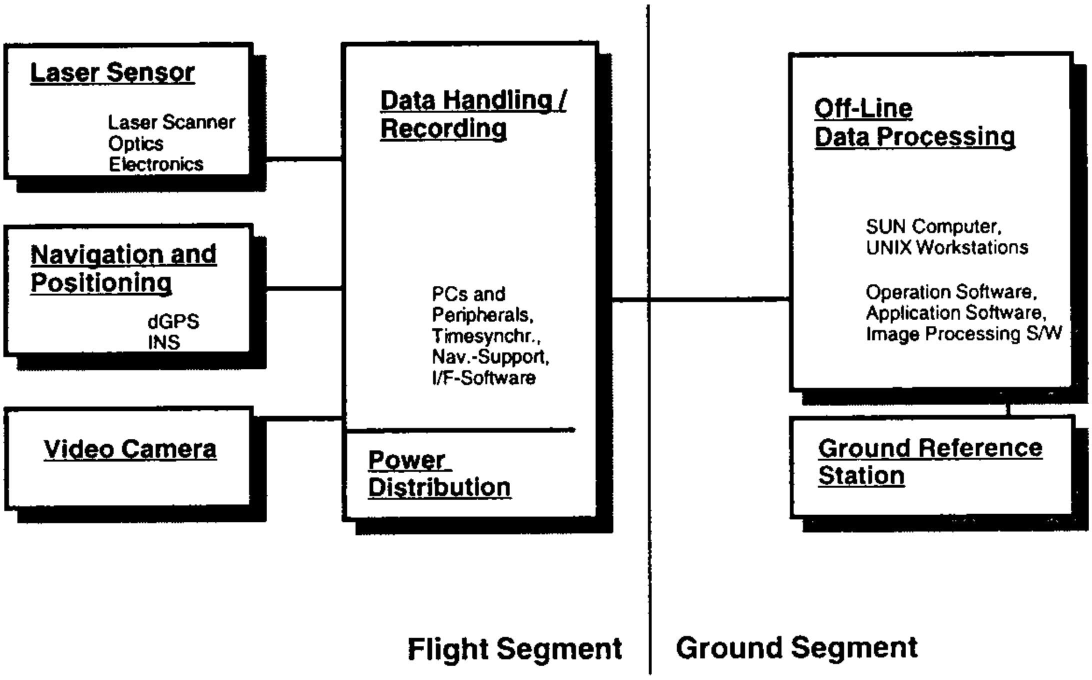

Figure 1: TopoSys System Components.

2.1 The Flight Segment

The main elements on-board the aircraft are the subsystems: navigation / positioning, Laser Sensor, Video Camera and data handling / recording.

The system design of the navigation and positioning system is based on the integration of dGPS with an Inertial Navigation System (INS) for positioning and attitude determination. GPS, INS, Laser Scanner data and video images are stored in mass storage devices with help of two data handling computers. A time synchronisation facility ensures the precise synchronisation of data from these different sourcesduring the post-processing.

If necessary, the aircraft system can be equipped with an additional touch screen for display of premission flight plan data and real-time satellite aided navigation data ("navigation co-pilot" system). Optional, the system can be upgraded with a telemetry receiver and demodulator module for reception of dGPS corrections from ground.

The Laser Scanner Sensor is, beside the navigation and positioning system, a key element of the flight system. The eye-safe sensor operates in the Near Infrared Region at 1.54 µm and is based on a fiber optic line scanner technology. The architecture of the Laser Scanner is shown in figure 2.

At Daimler Benz Aerospace / Dornier these fiber optic Laser scanners have been developed and permanently improved for more than ten years. Today such Laser Scanners work as

- range imaging camera (for telemanipulations),
- Obstacle Warning /Avoidance Systems (for helicopters and off-road vehicles),
- docking sensors (to guide aeroplanes during the docking phase to the terminal).

For the here presented application, the proven technology has been slightly modified to meet the requirements for DEM generation.

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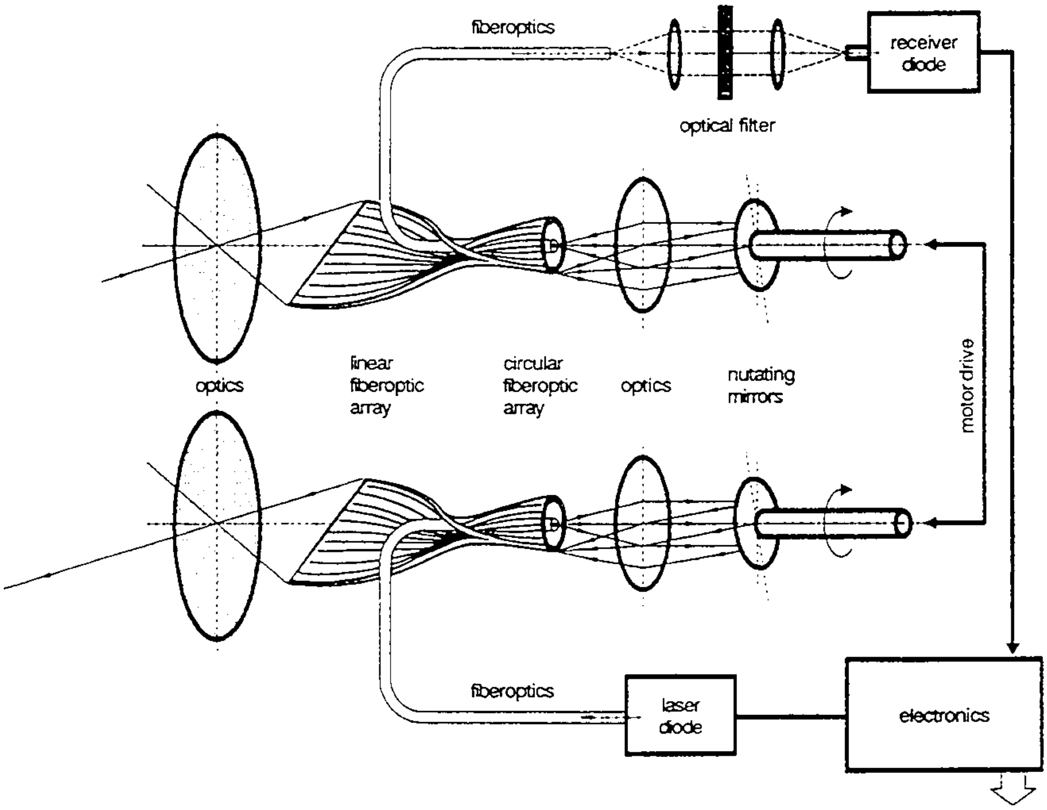

Figure 2: Architecture of the Laser Scanner.

The main task of the ground reference station located at a known position is to collect GPS data for post-mission dGPS processing. Furthermore, the station is regularly contacted to dump the sensor data collected by the data recording system, in order to clean the onboard mass storage devices for new data. The off-line processing system consists of several UNIX workstations. The key software packages are the TopoSys application software package for automatic DEM generation and the image processing software package which allows for e.g. DEM visualisation, DEM transforming into various cartographic projections, quality control.

3. OPERATIONAL PROCEDURE FOR DEM GENERATION

During a TopoSys survey, the aeroplane flies over the area which was - already in the mission planning phase - divided into parallel, slightly overlapping stripes. With the "navigation co-pilot's" help the pilot is able to survey the area according to the mission plan. All the sensor data (GPS, INS, Laser Scanner, reference video) are registered and time-tagged in parallel.
The first step in the off-line processing is the complete recalculation of the flight dynamics from the GPS/INS data. Then first guess, single stripes DEMs are calculated for the whole survey area. By considering objects which are present in adjacent strips, an enhanced set of position and attitude data for the Laser Sensor is determined. The enhanced single DEM strips are then merged into a complete DEM of the survey area and, with help of some small reference DEMs, the relative DEM is transformed into absolute co-ordinates. After quality control, the final DEM is available as 16 bit raster data in various co-ordinate systems and data output formats.

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4. PERFORMANCE PARAMETERS

The TopoSys system has been designed to produce high-precision DEMs. Performance parameters of hardware components (e.g. Laser Scanner, INS) as well as associated software packages have been developed to allow a maximum accuracy of TopoSys DEMs of x, y, z = 0.3, 0.3, 0.1 m.
The main performance parameters of the TopoSys' flight segment are given in table 1.

sensor type	pulse modulated Laser Radar
range	> 1000 m
scanning principle	fiber optic line scanner
transmitter	solid state at 1.5 µm
measurement principle	run-time measurement
scan frequency	300 Hz (adjustable)
field of view	+/- 7E
number of pixels per scan	127
swath width (at 10000 m flight height)	250 m
accuracy of a single distance measurement	< 0.3 m
resolution of a distance measurement	< 0.1 m
Laser classification	class 1 by EN 60825 (eye-safe)
size sensor	30 cm * 30 cm * 30 cm
mass sensor	< 20 kg
size data recording system	19" rack, 1.2 m high
mass data recording system	80 kg
power requirements	28 VDC, 15 A

Table 1: Performance parameters of TopoSys' flight segment.

5. HISTORY AND OUTLOOK

The feasibility of producing high-precision DEMs with a line scanning Laser sensor has been proven within the last two years. The first step in this direction was in spring 1993, when a DEM of a small part of the river Salzach had to be generated within a pilot project. As the feasibility of the method could be shown at that time, further measurement campaign (Hannover, October 1993; Solothurn, March 1994) followed. As reference, figure 3 shows a DEM of a section of the city of Hannover - for better orientation a scanned aerial photograph has been superposed to the original DEM data.
The experiences gained with that prototype of the TopoSys system, strongly influenced the design of the new system, which has been outlined above. The presented TopoSys system is just now in the final integration; test flights and pilot project are scheduled for the period September / October 1995. After debugging and final system tuning, which are expected to be finished in late autumn 1995, the operational service will start.

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Figure 3: Section of the TopoSys DEM of Hannover city.