

# Measurement of dump heights at conveyor bridges alliances

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**ABSTRACT:** The successful completion of the project for measurement of dump heights at conveyor bridges alliances was the start for online digital terrain modelling in real time mode. Important technical equipment of the solution are Laser mirror scanners, GPS in real time kinematic mode, Ethernet based process data networks, ruggedized industry PC and special applications for data handling, storage and visualization. The results are very good and turn out to be better than expected. On screen applications are practical assistance tools for machine operators. The same view and a couple of special functions were realized for mining engineers. The user front ends were distributed web-based. The application on spreader is presently in progress.

## 1 INTRODUCTION

The mining and the conversion into electricity of lignite in three open-pit mining regions and four lignite power plants is the core business of Vattenfall Europe Mining & Generation in eastern Germany.

The raw lignite mining output of 2005 was 59.0 million tons. But nearby we have to pump a lot of water day and night and have to move up to 6 or 7 cubic meter of overburden for every ton of lignite. Our open cast mining technology you can see at Figure 1, shortly described in following steps:

- Preparation of pre-mining area
- Groundwater lowering (dewatering)
- Pre-cut overburden moving
- Overburden conveyor bridge operation
- Coal extraction
- Reclamation and groundwater recharge.

The capacity of the whole removal is determined by the overburden conveyor bridge unit, there handles layers of more than 60 meter of overburden, in two working levels, uncovering the coal seam.

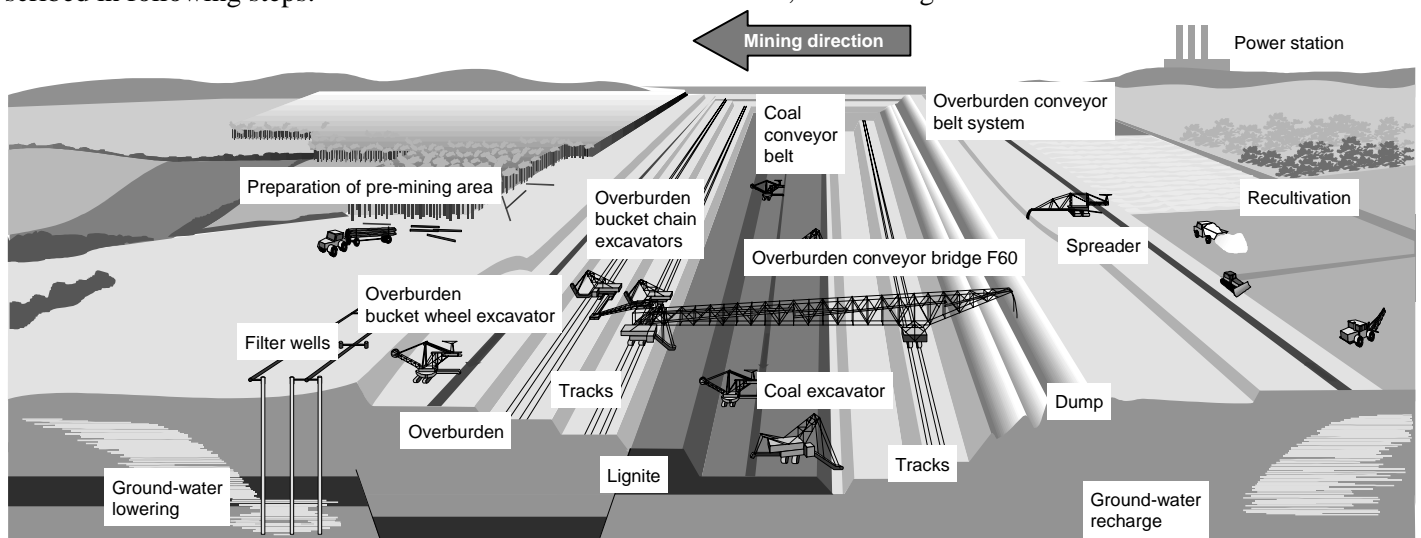


Figure 1 Opencast Mining Technology

The bridge unit includes three big bucket chain excavators. The yearly removal capacity of one alliance is about 100 million cubic meter overburden. The bridge and the connected excavators travel on rails for typical distances of about 4000 meter and move the overburden masses across the conveyor system with a length of up to 600 meter directly to the dumping site, see Figure 2, of the pit.



Figure 2 Pre-dump and high-dump areas

The so-called pre-cut units carry out the first cut overburden. They typically consist of a large bucket-wheel excavator, a few kilometre long conveyor system and a spreader. The conveyor line rounds the pit. A comparison of these two overburden technologies ends with cost benefits by overburden conveyor bridges. But the direct removal of overburden has one difficulty – the direct influence of dump problems like slides, slope alterations, fractures and other movements. The observance of geotechnical targets at all times is the requirement for more cost efficient overburden movement with conveyor bridges in our open pit mines. First ideas (Tusche&Stange 1965) were discussed in the research and development process of overburden conveyor bridges class F60.

Today we know and accept the necessity of measurement systems for an efficient dumping process in combination with graphical interfaces for operators and engineers (Hempel 2001).

The real time and online operation of such a system is the goal.

## 2 TECHNOLOGY

To produce the requested database local or global digital terrain models (DTM) can be used. An overview of terrestrial laser scanning technology for mining application you can find in (Ostner&Schulz 2002) and (Güntsch et al. 2000).

The processed data could be stored in a regular pattern with a point spacing of one meter. The cross points of the grid mesh are determined by GPS in-

formation. So the data handling is like conventional terrestrial surveying methods based on Gauss-Krüger RD 83 coordinate systems.

Our surveying technology is to win and add the third dimension to the 2D-scanning technology by the regular motion of mining machinery like overburden conveyor bridges or spreaders in their working processes. On this way without post processing of data we get a real time and online surface model of the working area with a high precision and actuality.

In a parallel application we convert the surface data in a local DTM. This is helpful for operators and process line engineers to compare set points with actual data. So it is possible to control the movement of overburden and building up a dump.

The view of a shift result or a request of historical data is based on a data warehouse. Detailed and aggregated information could be offered as special reports. The export of data into another mine planning systems is possible.

## 3 REQUIREMENTS

The digital terrain model must have a high accuracy, this means better than:

- $\pm 0.05$  m in lateral directions (x and y)
- $\pm 0.5$  m in vertical direction.

The modelling should start at the pre-dump site and has to carry out the total dump geometry up to the high dump of the F60 dump system. Because of the experience of landslides and geological fault zones ends the measurement range just 30 m behind the upper slope edge of the F60 high dump.

In (Tölzer&Meinig 2002) you can find detailed information about total dump geometry and stability investigations. An example of difficult geotechnical conditions and an idea of monitoring and control system to overcome the problems were discussed in (Fincke&Laube 2000). The target for mining technology is to reach a greater reliability without reduced stability coefficients and without reduced mining results.

Applications should base on a two-step-database. Pre processed distance values have to be stored in a relational data base on the mining machine. An aging mechanism is to use to limit the quantity of data. The area should be represented by about 4.000 x 1.000 data points (x,y,z) in RD 83 system. The visualization of data is to concentrate of the operator interface.

The data base in the second step is object oriented. A new data stream is to send time controlled (every 8 hours) to this base. The reconstruction of time,

position and related local coordinates must be possible per selection.

A partial automated reporting system based on calculation methods of stability investigations has to be developed.

Harsh environmental conditions, low maintenance costs and very high reliability and availability are very preferable results for the complete system.

#### 4 SYSTEM SOLUTION

At the beginning of the development process we discussed and decided the system solution Figure 3 as the only way. Important system parts are:

- Laser scanner
- GPS system
- Infrastructure
- Data processing
- Visualisation
- Data storage
- Special applications

The basic principle of the development process was to create at first a common functional description for mining process purposes. This team work was supported by an external engineering partner. The same stuff got the order to attend the project up to the final step of the pilot application and in case of success as a system partner for intended investments.

The description and selection of appropriate equipment and technology was the second job. We decided to go different ways to find particularly suitable answers.

One of the core equipment is the laser scanner. With some practical experiences we selected a scanning principle – the 2D laser mirror scanning. For our application on overburden conveyor bridges we were looking for mid range scanners with a high accuracy and user selectable parameters. The scanner also must be stable in respect of a wide temperature range, shock and vibration as well as dust and soil. We tested scanners from different vendors under real application conditions and a scanner from RIEGL (Riegl) had the best test results. So we planned together the Laser Mirror Scanner LMS-Q500 Figure 4.

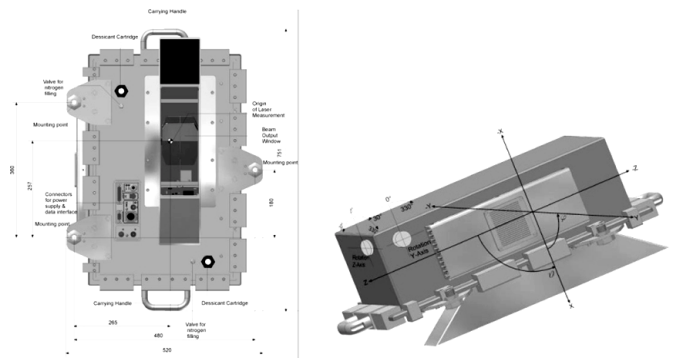


Figure 4 LMS-Q500

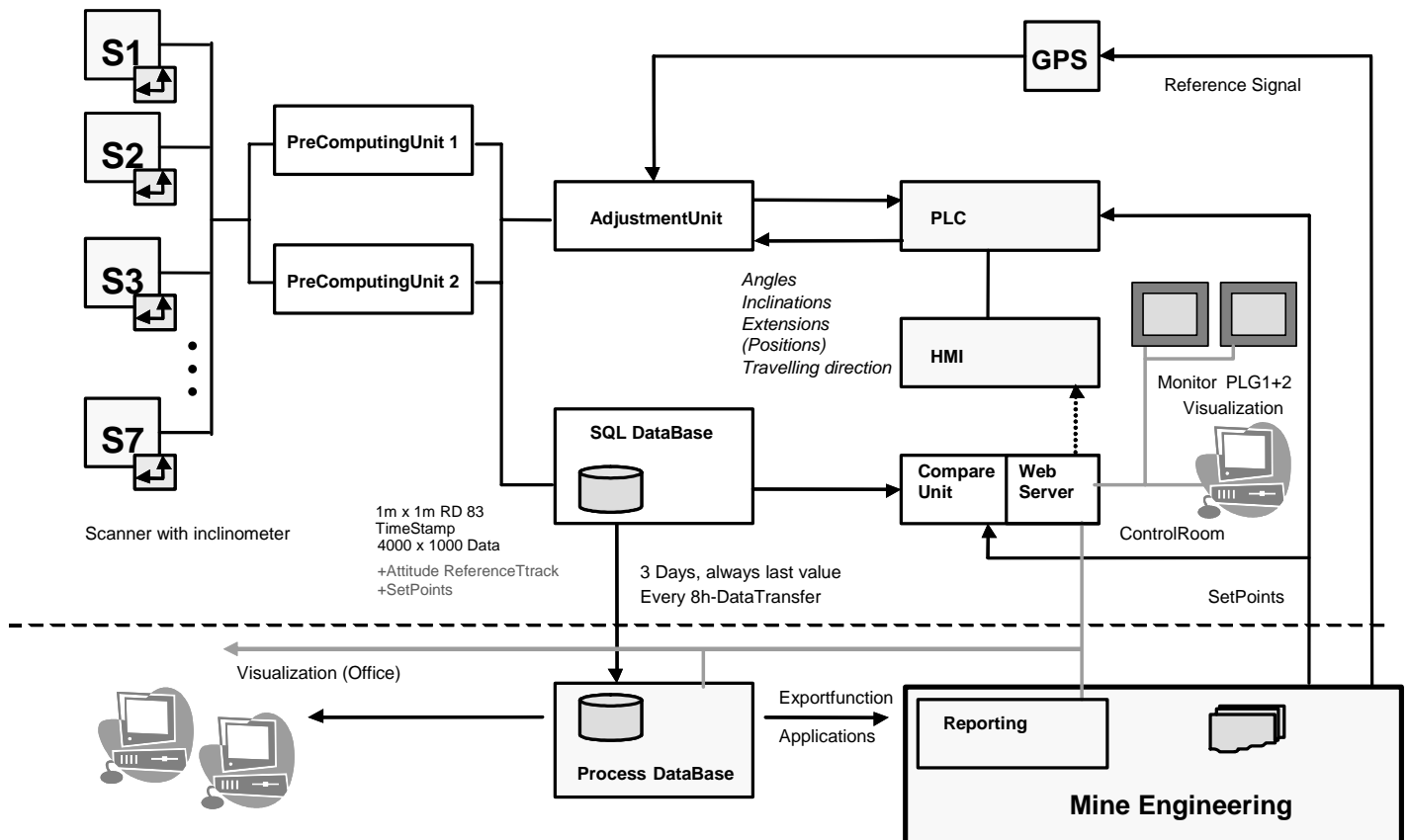


Figure 3 System solution

Table 1 Technical data of the laser rangefinder

Measurement principle	Time-of-flight measurement
Measurement range (10% refl.)	100 m
Minimum range	5 m
Measurement accuracy	±25 mm (typ.)
Measurement resolution	10 mm
Measurement rate	2.000 Hz
Laser beam divergence *	3 mrad
Eye safety class	Class 1
Laser wavelength	0.9 μm

\* 1 mrad corresponds to 10 cm beam width per 100 m distance

The scanner mechanism deflects the laser beam for multipoint distance measurement into precisely defined directions. So we get scan lines with a number of single pixels. The angular deflection of the beam is realized by a rotating scan mirror. The angular position of the mirror is detected by a direct coupled angle decoder. The angle read out resolution is  $0.002^\circ$ . We use a scanning range of 105 degrees at a scanning speed of 2 scans per second. In the result you have an angle step width of  $0.105^\circ$  and 1.000 points per scan.

The 3D scanning of surfaces like shown in Figure 5 is possible if you can recognize and integrate the motion of the machine e.g. of the scanner.

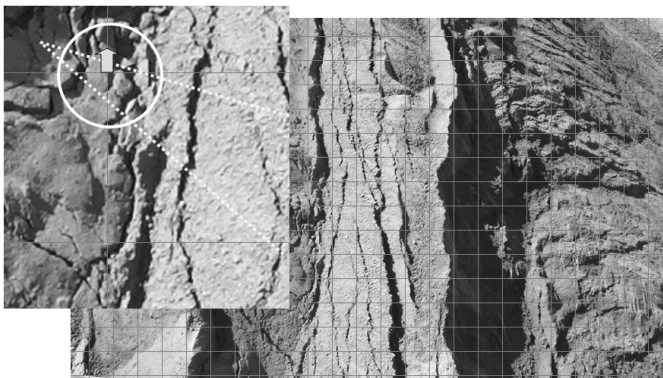


Figure 5 Surface scanning

The computing of a digital terrain model based on row data like distances, points, angles and times is only with a high accuracy possible, if you have mathematical models and a high available GPS system. We select MS Series receiver from Trimble. These receivers are designed for high precision navigation and location. With the real time kinematic techniques (RTK) the system achieves a centimetre-level positioning accuracy. RTK is based on at least two GPS receivers – a base receiver on an office building of the engineering stuff and two receivers on the overburden conveyor bridge. The base receiver takes measurements from satellites in view and then broadcast them together with his known location as reference signal to the receivers

in the mining area. A very good basic for that is a fibre optic based broadband communication. Vattenfall Europe Mining has a hierarchical, highly efficient process and communication infrastructure for local, regional and interregional areas (Petrich 2003).

The installation of seven scanners and two GPS receivers is shown at Figure 6.

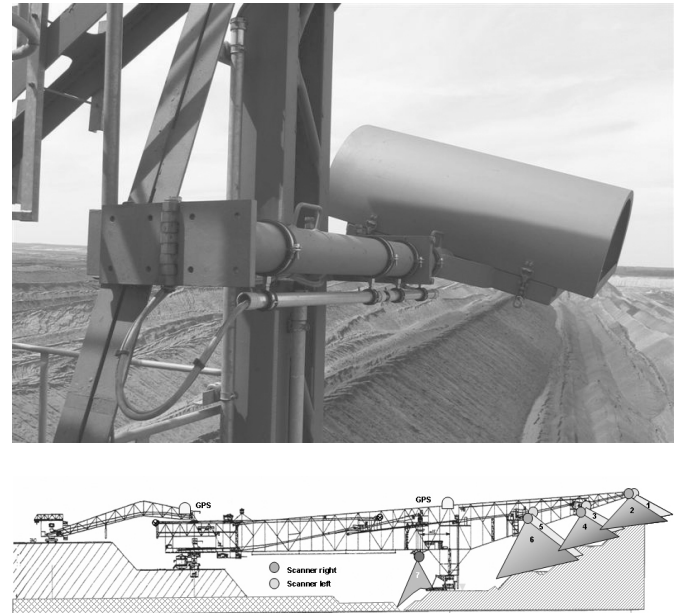


Figure 6 Installation of scanners and GPS

The measurement rates of the scanner, the motion speeds of the conveyor bridge and the fixed connected equipment, the telegram rates of GPS and some other important time pattern must be synchronized to each other.

The data processing is the way to win information from a lot of data. The pre-computing unit calculates the vertical height values for every cross point of the 1 m x 1 m grid mesh. A lot of statistics and knowledge is necessary for this job. Some theoretical basics you can find in (Elandaloussi et al. 1999). The interface between the computing unit and the scanner is also used for data communication in programming mode. Parameters and control data could be transmitted. The electrical interface is the standardized Ethernet.

The adjustment unit adapts the data stream (5 telegrams per second) of the GPS receivers and organizes the data exchange between the PLC and the height measurement system via OLE for Process Control (OPC). All units are connected to a switched Ethernet network.

The SQL data base, the compare unit and the web server are based on the Legato software suite. A central component of Legato® is the universal and platform independent database gateway.

Outstanding flexibility is possible through a built

in script engine and different module interfaces (OPC or TCP/IP interfaces to manufacturing, ODBC or native Oracle drivers to database and/or OLE automation/Com Client if required).

The Visualization of the local digital terrain model in connection with set points and helpful information for machine operators is realized web-based. A PC in the same ore in a connected network with a browser, a JAVA-plugin and a SVG-plugin is the minimal configuration to take part of the implemented features.

The sequential storage of data fields is a time controlled job. Every 8 hours a data transmission from the SQL data base (machine) to the process data base (control room) is taking place. Central stored data should be used with the special web-based application ZEDAS.

All technical equipment is rugged enough to withstand the temperature, vibration and shock conditions in mining environments. The industrial Compact PCI based PC technology is the preferred choice for our applications that require long-life, high-performance and low-maintenance.

## 5 RESULTS

Today we use dump height measurement systems and related digital terrain models in all three open cut mines with working overburden conveyor bridges class F60. The introduction of our system solution into practice was successful.

All technical components operate stable with a high availability and reliability. The verification of accuracy and plausibility was a challenge for all significantly involved partners and our own technical stuff. Mine surveyors of Vattenfall Europe Mining AG have the final say.

Three methods of confirmation were found:

- Position measurement in motion with the help of samples (targets with a high reflection coefficient)
- Measurement of longitudinal profiles as reference
- Comparison of scanned areas with results of airborne photogrammetry.

Some results are shown at Table 2 and Figure 7.

The differences in values for northing, easting and altitude are typical less than 0.1 m. The influence of accurate GPS function is significant. The connection to the reference signal must be stable. The visibility of satellites must be undisturbed. An incorrect parking position of the integrated repair crane of the overburden conveyor bridge tends to absolute disfunction of GPS RTK-mode.

By the way it is necessary to have a complete and tested model for all geometric ratios and some help of mine surveyors for measurements of steel structures. A mechanical drawing is only a drawing. Under production conditions the quality of the results is very good.

Table 2 Accuracy of points (measured in motion)

Position of samples	GPS-Enmessung E-BMA1 (Mittel Messungen v. 04./05.10.05)				Einmessung BIAS/KHM-System (Messung v. 05.10.05)				Differences of measurement results			
	mine surveyor			Station KAE	scanning			Station KAE	Northing $\Delta X$ [m]	Easting $\Delta Y$ [m]	Altitude $\Delta H$ [m]	Station KAE $\Delta$ [m]
	Northing X	Easting Y	Altitude H		Northing X	Easting Y	Altitude H					
UK KTS	5743094,922	5468350,625	-2,636	897,155	keine Ang.	keine Ang.	keine Ang.	keine Ang.	keine Ang.	keine Ang.	keine Ang.	keine Ang.
Vorschuettung	5743055,668	5468360,351	12,558	900,875	5743055,730	5468360,400	12,530	900,930	0,062	0,049	-0,028	0,055
OK Vorkippe	5743026,993	5468359,380	17,315	895,607	5743027,040	5468359,400	17,290	895,630	0,047	0,020	-0,025	0,023
UK 1.Abw urf	5742957,975	5468368,968	17,183	894,720	5742958,050	5468369,020	17,060	894,780	0,075	0,052	-0,123	0,060
OK 1.Abw urf	5742928,796	5468369,921	35,619	891,279	5742928,800	5468369,880	35,570	891,240	0,004	-0,041	-0,049	-0,039
UK 2.Abw urf	5742878,125	5468380,758	40,425	894,382	5742878,180	5468380,700	40,370	894,330	0,055	-0,058	-0,055	-0,052
OK 2.Abw urf	5742864,794	5468382,350	49,428	893,953	5742864,900	5468382,280	49,470	893,900	0,106	-0,070	0,042	-0,053
UK 3.Abw urf	5742798,272	5468390,503	48,850	892,022	5742798,290	5468390,320	48,890	891,840	0,018	-0,183	0,040	-0,182
OK 3.Abw urf	5742772,517	5468392,956	63,189	890,578	keine Ang.	keine Ang.	keine Ang.	keine Ang.	keine Ang.	keine Ang.	keine Ang.	keine Ang.

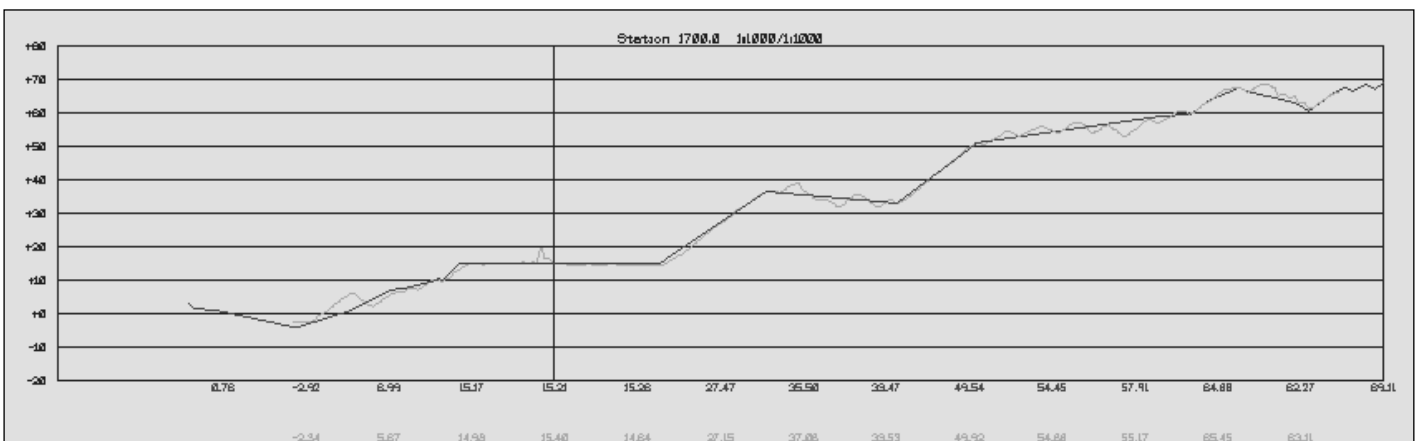


Figure 7 Accuracy of profiles (comparison with edges)

To be an assistance system for the operator of the mining machine a visual presentation, like Figure 8, is essential.

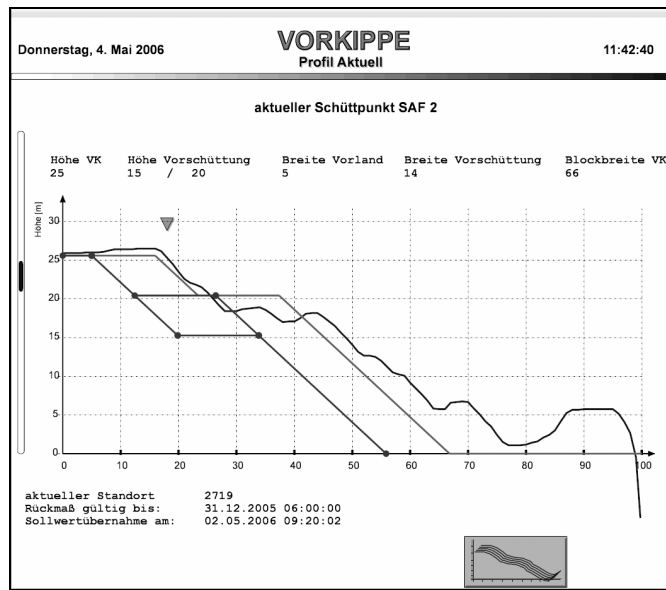


Figure 8 Operator interface pre-dump

Other information is provided real time and online by a menu bar of the web-based application:

Pre-dump actual/determined values as longitudinal profile in the position of active dumping point

High-dump actual/determined values as profile under the boom of bridge and as line chart for the whole bench

Diagnostics overview of intern technical functions like GPS, scanner, IPC units

Another ongoing part of the system solution is the support of engineering stuff for the control of operations. This is not a real time and online process but a job very closed to the production. The requirements in this connection are special in the manner described following:

- Storage of consistent data for a time of at minimum 100 days in Gauss-Krüger RD-83 coordinates
- Possibility of mining situations right in time and in related local coordinates
- Selectable areas for partly import of DTM in 3D
- Pre-computed reports of technological situation based on longitudinal profiles as table and graphic
- Realization of geotechnical automated investigation technology in reported tables

Some examples could demonstrate the reached standard shown in Figure 9 and Table 3.

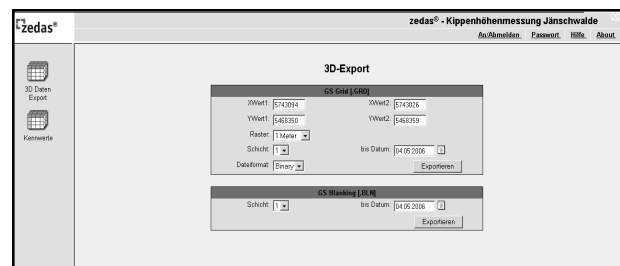


Figure 9 Data base and application 3D-Export

Table 3 Report pre-dump

		Stand vom:		letzte Messung:							
		04.05.2006 05:03		18.03.2006 04:56							
		Auswahl:		03.05.2006 Schicht 3							
Station	Datum	Fläche Sicherheit	Fläche Rücken	Blockbreite (Betriebswert) Vorkippe	Breite Vorland	Höhe VS min	Höhe VS max	Höhe VS	Höhe Vorkippe		
				Soll	Ist	Soll	Soll	Ist	Soll	Ist	
325	17.03.2006 08:07	ok	ok	44	19,8	15,4	15,4	17,8	20,6	20,9	
350	17.03.2006 08:10	ok	ok	44	19,8	15	15	17,6	19,9	20,4	
375	17.03.2006 08:15	ok	ok	44	20,8	14,5	14,5	17	19,3	19,8	
400	17.03.2006 08:20	ok	ok	44	32,8	14	14	17,5	18,6	19,1	
425	17.03.2006 08:24	ok	ok	44	21,8	13,5	13,5	15	17,9	18,3	
450	17.03.2006 08:29	ok	ok	40	29,8	12,9	12,9	16,3	17,2	17,5	
475	17.03.2006 08:33	ok	ok	40	20,8	12,4	12,4	13	16,4	16,8	
500	17.03.2006 08:37	ok	ok	38	21,8	11,8	11,8	12,9	15,7	16	
525	17.03.2006 08:40	ok	ok	38	19,8	12,7	12,7	12,8	17	17,3	
550	17.03.2006 08:43	ok	ok	38	20,8	13,7	13,7	16	18,2	18,5	
575	17.03.2006 08:46	ok	ok	38	18,8	14,6	14,6	17,1	19,5	20	
600	17.03.2006 08:50	ok	ok	47	20,8	15,5	15,5	17,2	20,7	21	
625	17.03.2006 08:53	ok	ok	47	16,8	15,5	15,5	16,3	20,6	20,9	
650	17.03.2006 08:56	ok	ok	47	16,8	15,4	15,4	17	20,6	20,9	
675	17.03.2006 08:59	ok	ok	47	15,8	15,4	15,4	16,2	20,5	20,9	
700	17.03.2006 09:08	ok	ok	47	16,8	15,3	15,3	17	20,4	20,8	
725	17.03.2006 09:11	ok	ok	47	16,8	15,1	15,1	16,8	20,1	20,4	
750	17.03.2006 09:14	ok	ok	47	16,8	14,8	14,8	15,6	19,8	20	
775	17.03.2006 09:16	ok	!	47	13,8	14,6	14,6	14,4	19,4	19,8	

## 6 APPLICATION ON SPREADER

Due to the positive results of the system solution described above it should be possible to applicate the technical solution on spreader. In (Bulowski & Körber 2004) and (Bulowski & Keulertz 2002) you can find project ideas and descriptions of GPS-assisted dumping.

The measurement of heights based on scanning technology in connection with GPS seems like a conveyor bridge solution – but it isn't real the same! As a result of the preliminary study (Elandaloussi & Müller 2004) we found some difficulties and risks:

- Motion sequences of bridge and spreader are total different
- Organization and engineering of dumping processes
- Dumping technology
- Vibration and shocks on the spreader boom
- Mechanical problems with additional load on the boom of the spreader
- Selection of a suitable visual assistance for the operator

Since March 2006 we are testing the application of the approved solution with special extensions for spreader based dumping. First results in accuracy are better than 0.5 m, but we have to do a lot of optimization work.

## 7 PARTNERS

This kind of projects demands team work. The complexity of the development, test, optimization, current use and preventive and corrective maintenance is a must for close cooperation with partners. Partners are not only the specialists from BIAS (Bremer Institut für angewandte Strahltechnik) with know how in laser measurement and measurement value processing. The extension of infrastructure was an extension of a well running process data network. The experience of Fleischhauer Ingenieurbüro Cottbus was very important for the success of the project. The hardware and software for the process IT were planned, delivered and activated by EWG Automation. The engineering work from an idea management to a well sorted list of requirements and the formulation of text files as description and tables for detailed tenders were the main focus of KOARK Automation. The monitoring of all project steps was included.

One of the most important things is to organize the partnership with and between mining and technical engineering stuff.

## 8 SUMMARY AND OUTLOOK

The successful completion of the project for measurement of dump heights at conveyor bridges alliances was the start for online digital terrain modeling in real time mode. The results are very good and turn out to be better than expected. Applications for visualization are practical assistance tools for machine operators. The same view and a couple of special functions for mining engineers were realized. The applications were distributed web-based via intranet. The application on spreader is presently in progress.

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